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Ref #61

OFFICE OF ENVIRONMENTAL AFFAIRS

4-25-80

FINAL SUMMARY REPORT
SPECIAL SUMMARY EVALUATION

DARTMOUTH
WATER SUPPLY 120

RECEIVED

MAY 21 1981

COASTAL ZONE MANAGEMENT
Exec. Office of Environmental Affairs

P.C.B. MONITORING SYSTEM

GIDLAB ENC-647

NOTE: This report is prepared in response to the request of Mr. David Vincent, Chairman of the Conservation Commission, on March 28, 1980 for a special summary report "written in lay terms as much as possible."

I. INTRODUCTION

A. Early Background

The Conservation Commission of Dartmouth first expressed its concerns to GIDLAB for monitoring the Paskamansett area and for P.C.B. late in 1975 and early in 1976 under the chairmanship of Ms. Judith Dautel. On February 9, 1976, Gidley was officially authorized as Consultant and Agent by the Conservation Commission with access authority in Dartmouth. Under the chairmanship of Judith Dautel, John Reardon and Gerald Franklin, Gidley has served as professional consultant for the Conservation Commission (with and without charge) on various conservation problems. See previous section in this Consolidated Report entitled "Background."

B. Current Background

After several presentations and preliminary testing by GIDLAB (without charge in 1977 and 1978), the Conservation Commission sponsored an article which was duly approved by Special Town Meeting vote on September 27, 1978. Because of the considerable delays since 1976 and in an effort to afford Dartmouth maximum and earliest possible protection, GIDLAB voluntarily, in November 1978, considerably added to the number of Dewline Sensor stations already installed in 1976 and 1977 (see reports to Judith Dautel, Chairman).

On February 26, 1979, the Conservation Commission accepted GIDLAB's "bid for monitoring P.C.B.s in the Town of Dartmouth." On March 19, 1979, the GIDLAB contract was reviewed by Town Counsel Leonard E. Perry and found to be "in legal form which will bind both parties." The contract was signed by the Conservation Commission with "an effective date of March 1, 1979" and "a termination date of April 1, 1980." GIDLAB was authorized by the Conservation Commission specifically as its Consultant and Agent for this project on April 24, 1979. The reader is referred to the previous section entitled "Background" for these references and, of course, to the files of the Conservation Commission.

FINAL SUMMARY REPORT
P.C.B. MONITORING SYSTEM

II. OBJECTIVES (Continued)B. Methodology of Procedures for Achieving the Objectives (continued)

relatively fixed subsequent Annual Monitoring Program—however, the original study must not be, indeed cannot be, rigorously fixed if it is to be scientifically valid. The initial hydrogeochemical study is analogous to a scientific occupational hazard survey of a new chemical factory producing new chemical products to determine the hazard sites, the significant chemicals, the relative toxicity, etc., on the basis of which study a relatively rigid future periodic inspection schedule may be established. Or more succinctly, the initial P.C.B. study is the thorough professional insurance survey on which a routine insurance policy issues; or the pioneering architectural design of a building upon which specifications such a building will be faithfully constructed in the future.

III. TEST RESULTS FROM THIS PROJECTA. Introduction

The test results, "observations, discussion of the results, conclusions with the reasons for them and recommendations," have been previously reported on a continuing basis and as rapidly as possible to the Conservation Commission. GIDLAB refers the reader to the selection of the most pertinent interim reports which have been assembled in the previous section entitled "Test Results." GIDLAB can add little to these reports (except to summarize the data, results, conclusions and recommendations already presented) "written in lay terms as much as possible."

GIDLAB has always endeavored to present all its reports (written or oral) in those forms which it believes to be comprehensible by the Commission members—but, of course, requiring assiduous reading of each report. GIDLAB does not expect a Commission member to interpret the data nor to draw technical conclusions from the data especially contrary to the stated professional conclusions of GIDLAB on this same data. If any member has any questions regarding the interpretation of the data or the conclusions and recommendations thereupon, the concerned member should appropriately obtain such additional information or interpretation as may be desired from GIDLAB. GIDLAB has always offered to answer any questions concerning its reports.

B. Graph Presentation

GIDLAB does not believe graph presentation would facilitate understanding of the test results, but, on the contrary, would be very cumbersome,

FINAL SUMMARY REPORT
P.C.B. MONITORING SYSTEM

III. TEST RESULTS FROM THIS PROJECT (Continued)

C. Test Value Judgments (continued)

Very roughly, some of the background criteria upon which each conclusion or judgment is based may be grouped in major categories as follows:

1. Hydrogeologic factors of the site.
2. Soil chemistry of the site.
3. Water chemistry of the site.
4. Relationship of the chemistry of individual toxicants with other chemical factors present or absent.
5. Surface transport of leachate hydrogeochemical logistics.
6. Aquifer leachate transport factors.

Specifically, some of the judgment criteria considered were:

1. Structural bedrock geology.
2. Anticline occurrence.
3. Anticline rotation (direction and degrees).
4. Soil strata classification.
5. Soil exchange capacity (in milliequivalents per 100 grams).
6. Soil conductivity (in micromhos per centimeter).
7. Soil cation percents.
8. Saturation extracts.
9. Total soil anions.
10. Sodium adsorption ratio.
11. Soil permeability (centimeters per second).
12. Chemical constituents of the soil.
13. Chemical constituents of surface water-flowing.
14. Chemical constituents of surface water-stagnant.
15. Chemical constituents of the ground water.
16. Soil moisture percents at various depths.
17. Relationship of P.C.B. to soil surface area.
18. Chemical relationship of P.C.B., phenol and metals to organic content of the soil (adsorbent, chelating or reactive).

FINAL SUMMARY REPORT
P.C.B. MONITORING SYSTEM

III. TEST RESULTS FROM THIS PROJECT (Continued)

C. Test Value Judgments (continued)

4. Low distribution coefficient in soil. (GIDLAB conducted tests for phenol, lead and P.C.B. for this coefficient in landfill base soil.) The distribution coefficient, K_D , is the ratio of the equilibrium concentration of the test factor sorbed on soil or in a sediment divided by its equilibrium concentration in solution:

$$K_D = \frac{C_{\text{Soil}}}{C_{\text{Solution}}}$$

K_D results are expressed in milliliters of solution per gram of soil.

These tests showed a very low solution concentration of phenol in the soil.

5. Harshberger cylinder column tests: net leachate of phenol and P.C.B. through the podzolic and bog soils around the landfill showed substantially negative "transport" or leachate.

The above decisions for phenol were similarly based from decisions made for P.C.B. and other toxicants tested.

FINAL SUMMARY REPORT P.C.B. MONITORING SYSTEM

III. TEST RESULTS FROM THIS PROJECT (Continued)

D. Test Results (Tabulated) (continued)

FACTOR CHART

A	B	C	D	E	F	G
TEST FACTOR	MEDIA	LOW VALUE	HIGH VALUE	WORST SITE	NEXT WORST	E.P.A. LIMIT
4. Chromium	Surface Water	<0.01	0-12	Mail	#195	0.05***
	Sensor	<0.05	0-15	Mail	Conrail	0.05***
	Air Fall-Out	<0.02	0.9	Mail	#195	No Limit
5. Sodium Chloride	Surface Water	12	550	Mail	#195	250***
	Dump Wells	27	306**	Well #2	Well #1	250***
	Water in Dump Area	21.7	485**	Seep at Dump	Pond at Dump	250***
	Surface Water	12	550	Mail	#195	250***
6. Copper	Soil Core	6	7	Well #5	Well #4	No Limit Set
7. Arsenic	Soil Core	<1	1	Well #4	Well #5	No Limit
8. Silver	Soil Core	<1	<1	Well #4	Well #5	No Limit
9. Nickel	Soil Core	<1	1	Well #4	Well #5	No Limit
10. Nitrate	Dump Water	0.14	0.49	Dump Stream	Dump Seep	10
	Dump Wells	<0.1	<0.1	None	None	10
11. Nitrite	Dump Wells	<0.1	<0.1	None	None	1.0
12. pH	Dump Wells	6.1	8.3	O.K.	O.K.	5-9
13. Sulfate	Air Fall-Out	15	64	Mail	#195	No Limit

Continued

NOTES: ** = Not Significant Hazard to Paskamansett River System
*** = E.P.A. Drinking Water Standard

FINAL SUMMARY REPORT
P.C.B. MONITORING SYSTEM

IV. CONCLUSIONS AND RECOMMENDATIONS

After a thorough review of all our test results from March 1, 1979 to April 1, 1980 and other hydrogeochemical assessments (see the twenty-six judgment criteria, Section C, "Test Value Judgments" of Part III, Test Results from This Project), our conclusions remain the same as previously reported to you both via written and oral reports.

We repeat and summarize our conclusions as follows:

A. Phenol

1. Phenol is insignificant throughout the Paskamansett Basin area—values below E.P.A. toxic limits.
2. No significant phenol leachate originates from the New Bedford Landfill.
3. High soil exchange capacity, high pH, high dissolved oxygen, high organic soil matter (as previously detailed) would eliminate or minimize phenol leachate even if it occurred.
4. Further testing of phenol is not necessary.

B. Cadmium

1. No significant cadmium leachate originates from the New Bedford Landfill at present. Although the dump seep value was 9 times safe drinking water standards, this leachate has to travel such distances under such adverse conditions for transport (high pH, high soil exchange capacity, high organic matter and other factors—see list) that GIDLAB believes it will not reach the Paskamansett River system in sufficient concentration and amounts to pollute the Chase Road well field.
2. The air fall-out values at #195 and the Mall sites are significant indicators of potential pollution from these sources as previously reported by us. GIDLAB has long urged that all major storm drains be considered point discharges and regulated as such. Further Mall and road construction in the Paskamansett area should be carefully engineered to cope with the pollutant run-off problem.
3. All storm drains into the Paskamansett system should be monitored.

C. Lead

1. The lead leachate from the New Bedford Landfill is not significant (values are only 6 times safe drinking water limits) for the substantially same reasons cited for cadmium.

FINAL SUMMARY REPORT
P.C.B. MONITORING SYSTEM

IV. CONCLUSIONS AND RECOMMENDATIONS (Continued)

H. Sulfate

This may be a future parameter worth monitoring (especially at storm culverts) about once every year or two. GIDLAB does not currently believe it is a significant problem (the E.P.A. sulfate limit in drinking water is 250 milligrams per liter).

I. Total Organic Carbon (T.O.C.)

1. The leachate value from the New Bedford Landfill is not in itself a hazard to the River. However, we recommend monitoring, as high T.O.C. is often a factor contributing to the transport of toxic pollutants (e.g., phenol and certain metals).
2. The T.O.C. value at the Champion and Mall sites is high enough to be significant and worth further investigation in the future, as it is a chemical surrogate for certain pollutants.

J. Total Dissolved Solids (T.D.S.)

1. The dump leachate values are significant but not presently a hazard to the River. However, T.D.S. is often a valuable indicator of potential pollutants, and we, therefore, recommend monitoring of these wells be established on a regular basis.
2. The T.D.S. value at the Mall and #195 sites are high at certain seasons and in certain weather conditions. Total dissolved solids are in themselves not necessarily equally toxic at equal values, as the solid components vary—however, whenever the value exceeds 500 ppm, we believe monitoring is a good adjunct indicator.

K. Polychlorinated Biphenyl (P.C.B.)

1. The P.C.B. values in the landfill leachate wells are not a present hazard to the River.
2. However, obviously because of the known large amounts of P.C.B. in the landfill, a monitoring program should be established.
3. The primary present P.C.B. problem is from air fall-out on impermeable surfaces, such as Mall parking lots and roads. This is the probable reason for the occasional high values of P.C.B. in surface water at the Champion and Mall sites. This again indicates the desirability of controlling and monitoring storm drain culverts.

FINAL SUMMARY REPORT
P.C.B. MONITORING SYSTEM

IV. CONCLUSIONS AND RECOMMENDATIONS (Continued)

K. Polychlorinated Biphenyl (P.C.B.) (continued)

6. We, therefore, recommend the establishment of a monitoring program at the established landfill wells. If the P.C.B. in these wells markedly increases or reaches a value of 25 parts per billion, we recommend prompt progress in drilling the periphery of the landfill to determine bedrock and examine the feasibility of installing a bentonite slurry trench around the landfill. This procedure, of course, involves internal pump-out wells to prevent pressure build-out. Pump-out could be filtered through activated carbon to remove most of the P.C.B. before discharge down-gradient.

L. Establishment of a Regular Monitoring Program

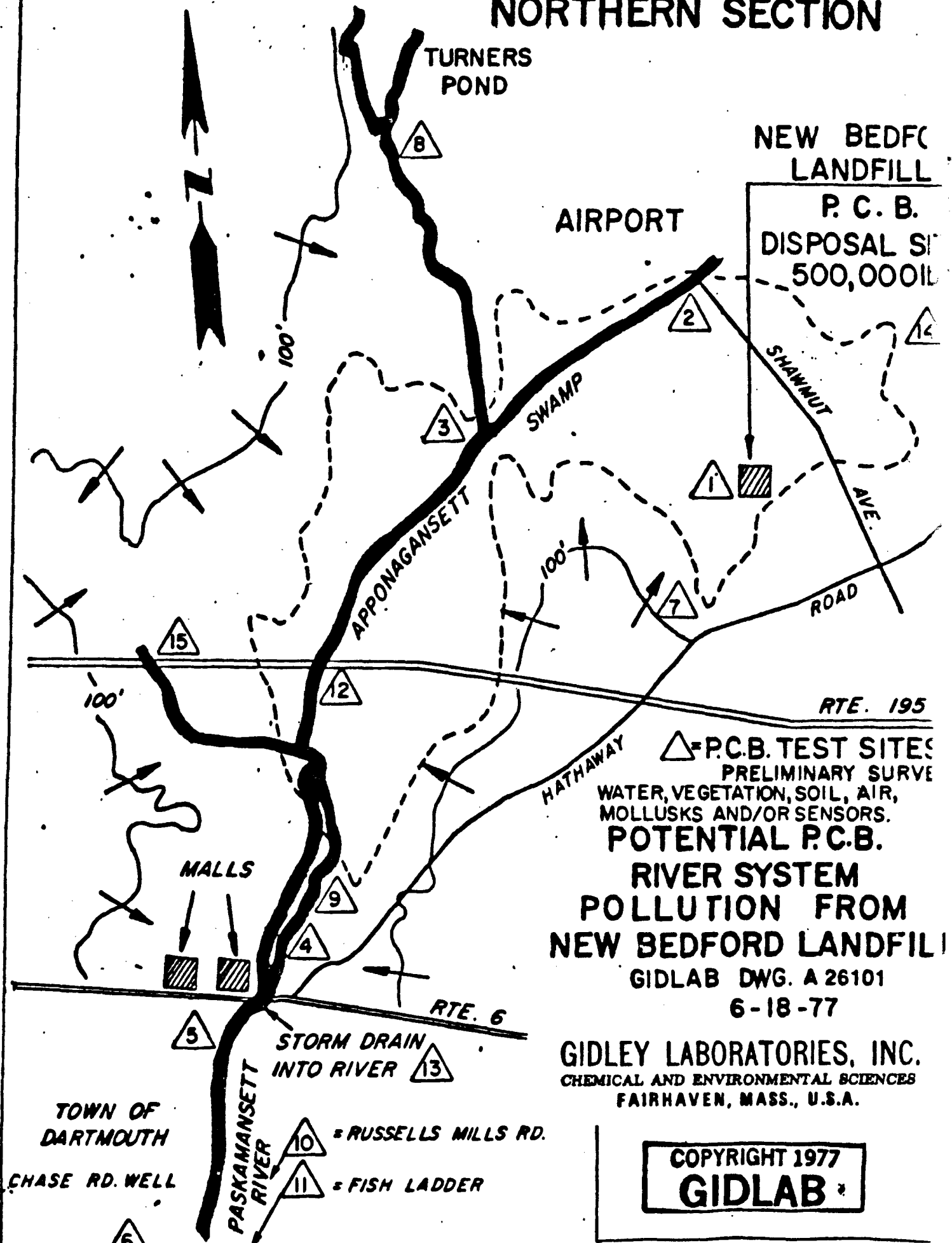
GIDLAB has previously outlined an appropriate monitoring program (revised April 8, 1980, GIDLAB Report ENC-647-AMP) to accommodate new circumstances of additional malls and the Slocum Road extension. The reader is referred to this program in the Consolidated Report (herein previously included).

M. Further Monitoring

GIDLAB's request to extend the contract was only for access to the New Bedford area and not for the Paskamansett area within the Town of Dartmouth, as GIDLAB has been testing continuously on a monthly basis from April 1979 to April 1980 in the Dartmouth area. Further testing in the Dartmouth area would be not only redundant, unnecessary for the objectives of the project but would be in excess of the contract itself which never contemplated more than a one-year duration.

GIDLAB has already reported water monitoring tests of leachate from the landfill monitoring wells for December 1979, January 1980, February 1980 and March 1980. Collection for April 1980 has already been assigned to GHR Engineering (GHR Lab will test for pH and chlorides and GIDLAB for other factors of well samples and also test and report on the Dewline Sensors which were installed in December). Although GIDLAB believes that the testing objectives of this project will have been more than adequately accomplished with the completion of the April testing, we will nevertheless voluntarily continue testing these wells through August of 1980 if you wish. If so desired, we will separately furnish an appendix report for this additional work. But based on all the evidence, we do not believe it will change our conclusions and recommendations as herein presented. In fact, it is our professional judgment that excessive testing (in view of the

PASKAMANSETT RIVER SYSTEM NORTHERN SECTION



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CHEMICAL AND ENVIRONMENTAL SCIENCES
FAIRHAVEN, MASS., U.S.A.

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GIDLAB

<u>Date sampled</u>	<u>Type Sample</u>	<u>Station Description</u>	<u>PCB Value ppb</u>
<u>NEW BEDFORD SANITARY LANDFILL</u>			
1/26/76	Water-grab	Groundwater from monitoring well GW-1	N.D.
	Water-grab	Groundwater from monitoring well GW-2	1.0
	Water-grab	Groundwater from monitoring well GW-3	N.D.
	Water-grab	Groundwater from monitoring well GW-4	N.D.
	Leachate seep- grab	Seep from near well GW-3	10
	Soil-split	Sample from drilling of monitoring well GW-3 (0-7.5 ft.)	7,500
	Soil-split spoon	Sample from drilling of monitoring well GW-3 (15-17 ft.)	N.D.
	Soil-split spoon	Sample from drilling of monitoring well GW-3 (15-17 ft.)	N.D.
<u>DARTMOUTH, MASSACHUSETTS MUNICIPAL WATER SUPPLY</u>			
2/2/76	Water-grab	Gravel packed well-raw water	N.D.
2/2/76	Water-grab	Gravel packed well-raw water	N.D.

*WWTP-Wastewater treatment plant

*Not detected. This indicates that the PCB level was below the detection limit.

INFO from EPA
file
1/15/76

SUMMARY OF PCB DATA

NEW BEDFORD, MASSACHUSETTS

<u>Date sampled</u>	<u>Type: Sample</u>	<u>Station Description</u>	<u>PCB Value ppb</u>
<u>NEW BEDFORD MUNICIPAL WATER SUPPLY</u>			
01/76	Water-grab	Little Quittacas Pond-raw	0.1
01/76	Water-grab	Little Quittacas Pond-finished	**N.D.

Little Quittacas Pond located in Rochester, Massachusetts, approximately 12 miles North of Aerovox.

Raw water samples taken by Aerovox and analyzed by Woodson-Tenent (6/11/75) showed 1.07 ppb PCBs.

AEROVOX CORPORATION

01/14/76	Water 8-hr. Comp.	Municipal water supply inlet at the plant	2.4
01/14/76	Water 8-hr. Comp.	North Trough Effluent to Acushnet River	51
01/15/76	Water 8-hr. Comp.	North Trough Effluent to Acushnet River	29
01/14/76	Water 8-hr. Comp.	Sanitary wastes at pump station discharging to WWTP*	400
01/15/76	Water 8-hr. Comp.	Sanitary wastes at pump station discharging to WWTP*	72

CORNELL-DUBLIER

01/14/76	Water-grab	Influent-public water supply in boiler room	**N.D.
01/16/76	Water-grab	Influent-public water supply in boiler room	**N.D.
01/14/76	Water-8hr. Comp.	Cooling water discharge to WWTP-South Moat	710
01/16/76	Water-8 hr. Comp.	Cooling water discharge to WWTP-South Moat	460

<u>Date Sampled</u>	<u>Type Sample</u>	<u>Station Description</u>	<u>PCB Value ppb</u>
1/76	Water-8 hr. Comp.	Cooling water discharge to WWTP- North Moat	2,900
01/16/76	Water-8 hr. Comp.	Cooling water discharge to WWTP- North Moat	580
01/14/76	Water-4 hr. Comp.	Boiler room effluent discharge to Acushnet River	110
01/16/76	Water-4 hr. Comp.	Boiler room effluent discharge to Acushnet River	41

NEW BEDFORD WWTP

07/19/76	Water-grab	WWTP influent	106
07/19/76	Water-grab	WWTP effluent	119
03/26/76	Sludge-grab	Before incineration	73,600
04/76	Sludge-grab	Before incineration	30,800

ACUSHNET RIVER

10/76	Sediment-grab	Acushnet River, approximately 60 meters downstream of Aerovox effluent discharge	620,000
08/24/76	Soft shell clam	Acushnet River East Bank .3 km down stream of Aerovox effluent discharge	53,000
	Soft shell clam	Acushnet River East Bank 1.1 km downstream of Aerovox effluent discharge	21,000
	Soft shell clam	Acushnet River East Bank 1.8 km down stream of Aerovox effluent discharge	23,000

NEW BEDFORD HARBOR

05/10/76	Sediment-grab	New Bedford Harbor approximately 500 meters downstream of Cornell- Dubilier	143,000
05/10/76	Sediment-grab	Near WWTP outfall	500
10/76	Sediment-grab	Near abandoned WWTP outfall	1,900



New England Aquarium

SITE SELECTION AND STUDY OF
ECOLOGICAL EFFECTS OF DISPOSAL OF
DREDGED MATERIALS IN BUZZARDS BAY,
MASSACHUSETTS

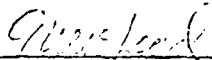
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By: T. Gilbert, A. Clay, A. Barker

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15 October 1973

TABLE OF CONTENTS

Title Page	i
Table of Contents	ii
List of Figures	iii
List of Tables	iv
I ABSTRACT	1
II INTRODUCTION	2
A. Physical Description of Buzzards Bay	2
B. Benthic Fauna	3
C. Continuing Research Activities	5
III RESULTS AND DISCUSSION	7
A. Sampling System	7
B. Water Analyses	7
C. Sediment Analyses	13
IV CONCLUSIONS AND RECOMMENDATIONS	23
A. Selection of a Dumping Site	23
B. Dumping Procedure	24
C. Environmental Impact	25
D. When to Dump	28
E. Alternatives	28
REFERENCES	34
APPENDIX 1 PROCEDURES FOR SEDIMENT ANALYSIS	36
APPENDIX 2 DETERMINATION OF SULFIDE IN MARINE SEDIMENTS USING A SPECIFIC ION ELECTRODE	40
APPENDIX 3 CRITERIA FOR THE SELECTION OF DISPOSAL SITES AT SEA	61
APPENDIX 4 CONTRACT WORK STATEMENT	67

LIST OF FIGURES

	Page
1. Buzzards Bay Sample Locations	8
2. Grain Size Distribution of Sediments	20
3. Sediments of Buzzards Bay (from Hough)	22
4. Alternative Disposal Sites	32

LIST OF TABLES

	Page
1. Water Quality Analysis Results	9
2. Trace Metals in the Water Column	12
3. Organic Matter in Sediments	14
4. Trace Metals in Sediments	15
5. Moore vs. N.E.A. Sediment Data	17
6. Sulfide and % Solids in Sediments	19
7. Maximum Increase in Metal Concentrations of Buzzards Bay Waters Due to Dumping	30

I. ABSTRACT

A grid of 14 sampling stations was set up, and between 22 May and 29 May, 1973, surface and bottom water and grab and core sediment samples were taken from the research vessel Monamet. Water samples were analyzed for the routine water quality parameters and also for five heavy metals. Sediment analyses included grain size distribution, % solids, % organic material (volatile solids), oil and grease, polychlorinated biphenyls, total sulfide, and eleven heavy metals.

The results of these analyses show the waters of Buzzards Bay to be well mixed and similar in quality to the nearby continental shelf waters. The only significant fresh water influence detected was from the Acushnet River and New Bedford/Fairhaven Harbor, as measured at Station 5. Sediment analyses show no significant differences from the results of studies carried out in 1934 and in 1953 for grain size distribution and trace metal concentrations. Fine grained deposits in the south central portion of the bay are high in sulfide and contain >5% organic matter, but only small amounts of geochemical and pesticide residues. Because of the nature of the sediments in this area and the nature of its benthic fauna assemblage, a dump site there has been proposed for the disposal of the dredge materials from Fairhaven Harbor. The environmental impact of this operation should be minimal although the effects of the elevated petroleum residue levels found in Fairhaven dredge site samples will not be clearly established until further testing is carried out. Alternative sites and methods for disposal have been evaluated.

II. INTRODUCTION

A. Physical Description of Buzzards Bay

Buzzards Bay has been the subject of considerable scientific investigation, especially in the areas of mineralogical sediment characterization and the nature of benthic infauna. The results of these previous studies have served as checks of the data obtained in the present work and in some cases give a much more detailed picture of the sediment phase of Buzzards Bay than were obtained by our limited sampling regimen.

Physically, Buzzards Bay is a non-estuarine embayment approximately 46 km long by 19 km wide with an average depth of about 11 meters. While the area of the Bay is 620 km^2 it drains a land area of only 1000 km^2 . This land area is low, with small hills and numerous lakes and marshes. Because of flat topography and also because of good vegetation cover, erosion of the land, and therefore natural sedimentation in the Bay, takes place slowly.⁽¹⁾ In fact, the maximum annual deposition rate has been calculated to be 2.3 mm in the unconsolidated upper layers.⁽²⁾

The waters of Buzzards Bay contain consistently high levels of dissolved solids: salinity varies from 29.5 to $32.5 \text{ }^{\circ}/\text{oo}$.⁽³⁾ The annual maximum bottom water temperature is about 21°C ., the minimum is -1°C .⁽⁴⁾ According to Moore,⁽⁵⁾ tidal currents are the most important source of energy for sorting and sizing the bottom sediments since the Bay is protected from large, long period open ocean waves. However, under stormy conditions

wave action can effect resuspension of the bottom sediments.

Tidal velocities in most of the bay are not large, usually less than 1 knot maximum. Stronger currents are encountered at the mouth of the bay, near the entrance to the Cape Cod Canal and between the Elizabeth Islands. These strong currents are reflected in the coarse nature of the bottom sediments in these areas with sand and gravel deposits common. Predominately silt and clay sediments line the bottom in the middle-southern portions of the bay where the bottom topography is relatively flat and between 14 and 20 meters below the surface. In that portion of the bay north of 41°35'N latitude the water depths are generally less than 13 meters and tidal velocities are variable. The result is a bottom with scattered patches of silt and clay, fine sand and coarse sand and gravel. The bottom sediments appear to be in an overall stable equilibrium. Moreover, the textural patterns found in the 1930's by Hough⁽¹⁾ were essentially the same as those found by Moore⁽⁵⁾ in the 1950's.

B. Benthic Fauna

The distribution of bottom texture determines the level and type of infauna and epifauna populations. Sanders⁽⁶⁾ has found two distinct communities of infauna in Buzzards Bay. In areas of stronger tidal currents and coarse grain sediments a group of filter feeding organisms dominated by species of the genus Ampelisca are most abundant. In addition to producing a

stable sediment substrate, the stronger current activity brings more potential food to the filter feeders. On the other hand, the weak currents over mud bottoms allow suspended organic matter to settle out and so provide nourishment to colonies of deposit feeding organisms, dominated by the primitive bivalve mollusc, Nucula proxima, and the polychaete, Nephtys incisa. The presence of burrowing bottom feeders can have a significant effect on the physical structure of bottom sediments.⁽⁷⁾ Such organisms, through their metabolism of the mud, generate fecal pellets which granularize an otherwise finely divided sediment and increase the likelihood of resuspension under even small tidal current shear forces. In fact, there is a considerable increase in the turbidity of the bottom waters of Buzzards Bay, caused in part by the activity of sediment feeders, during periods of maximum tidal velocity.^(8,9) That the unstable silt/clay sediments have been retained over the years is probably due to the asymmetrical tidal flow: the duration of ebb current is much shorter than the flood current.⁽⁹⁾

In addition to the work of Sanders, Rhoads, Young and others concerned with the macrofauna of Buzzards Bay, Weiser⁽¹⁰⁾ has done an extensive study of the meiofauna of the area. This classification includes microscopic organisms as well as those just visible to the unaided eye. In this group were observed a number of species of nematodes, but different population assemblages were found in the sand and the silt/clay areas.

C. Continuing Research Activities

At the present time there is additional scientific research under way or planned for Buzzards Bay, Massachusetts. Donald Rhoads of Yale University is continuing studies of the high turbidity layer in bottom waters over fine silt and clay sediments, examining its seasonal fluctuations and chemical and biological composition. Kenneth Tenore of Woods Hole Oceanographic Institution is running aquaculture experiments in the vicinity of Quissett Harbor. Howard Sanders of WHOI is continuing his monitoring of the effects of the Falmouth oil spill on marine organisms in the bay, and Carl Turekian of Yale is monitoring the levels of trace metals in tissue of fish living in the bay and comparing these results with analyses of similar fish living in Long Island Sound. A group at Southeast Massachusetts University, including Professors Robert Edgar, James Cox and Frank O'Brien, have proposed a study of nutrients and productivity in waters along the western shoreline of the Bay.

The Massachusetts Division of Marine Fisheries maintains an inventory of the fish population of Buzzards Bay. While commercial net fishing is prohibited, there is extensive game fishing in the bay. Tautog, flounder, and sculpin are among the most common bottom feeding game fish. In addition, there are important migratory populations of mackerel, striped bass, bluefish, fluke, scup and sea bass. The time of spring migrations can extend from mid-March to mid-July and the fall migration may continue into early November.

Finally, in considering a site in Buzzards Bay as a disposal

area for dredge spoil one should be aware of the provisions of the Massachusetts laws concerning activities of this type in marine sanctuaries. Under Chapter 742 of the Acts and Resolves of 1971 of the Massachusetts General Court, a "Cape and Islands Ocean Sanctuary" has been established which includes all of Buzzards Bay landward of a line extending from Buzzards Bay Light to the Rhode Island-Massachusetts state line. Banned from this area is the alteration of bottom sediments, including the removal of sand and gravel deposits and the disposal of commercial and industrial wastes. There are exceptions to the disposal ban, but these do not include dredged harbor spoil. Whether or not such spoil was intended to be included in the disposal ban is not clear from the wording of the law and certainly should be clarified before the dredge spoil disposal plans are finalized.

What follows is a summation of the sampling and analyses carried out as a part of our contract. The data are interpreted in light of the seasonal and tidal conditions present during sampling, and, in the case of turbidity, are compared with the observations of Rhoads.⁽⁹⁾ The rationale used in selecting a site for disposal will be set forth and the possible ecological effects of the dumping operation, including the long-term disposition of the spoil, will be postulated. The appropriate time for and method of disposal will be discussed.

III. RESULTS AND DISCUSSION

A. Sampling System

To evaluate the present condition of Buzzards Bay, a grid of fourteen stations as shown in Figure 1 was established. The original plan was to sample each station during slack tide for surface water, bottom water, a sediment core, and a sediment grab sample. However, restrictions on vessel use and a 1-1/2 month delay of availability of the Manamet forced a readjustment in plans and a delay in our analysis schedule. These restrictions resulted in a lack of coordination with the tidal phase, producing an irregular sampling pattern with respect to the tide. Weather conditions, rough seas, and bottom composition disallowed obtaining core samples at three stations.

All water samples were analyzed on site for temperature, pH, salinity, total coliform, turbidity, dissolved oxygen, and chlorophyll⁽¹¹⁾. Analyses of ammonia, nitrite, nitrate and total phosphate were performed on an average of 4 hours after sampling. Water samples for trace metals were preserved with hydrochloric acid, frozen, and analyzed within three weeks of sampling. The sediment cores and grab specimens were frozen and subsequently analyzed. Sediment analysis methods are described in appendix 1.

B. Water Analyses

The results of water analyses, tabulated in Table 1, for surface (S) and bottom (B) samples, indicate good mixing of the water column. As can be seen from the data, the average salinity is 32.0 and the average pH is 7.93 with little difference between

FIGURE 1
BUZZARDS BAY
SAMPLE LOCATIONS

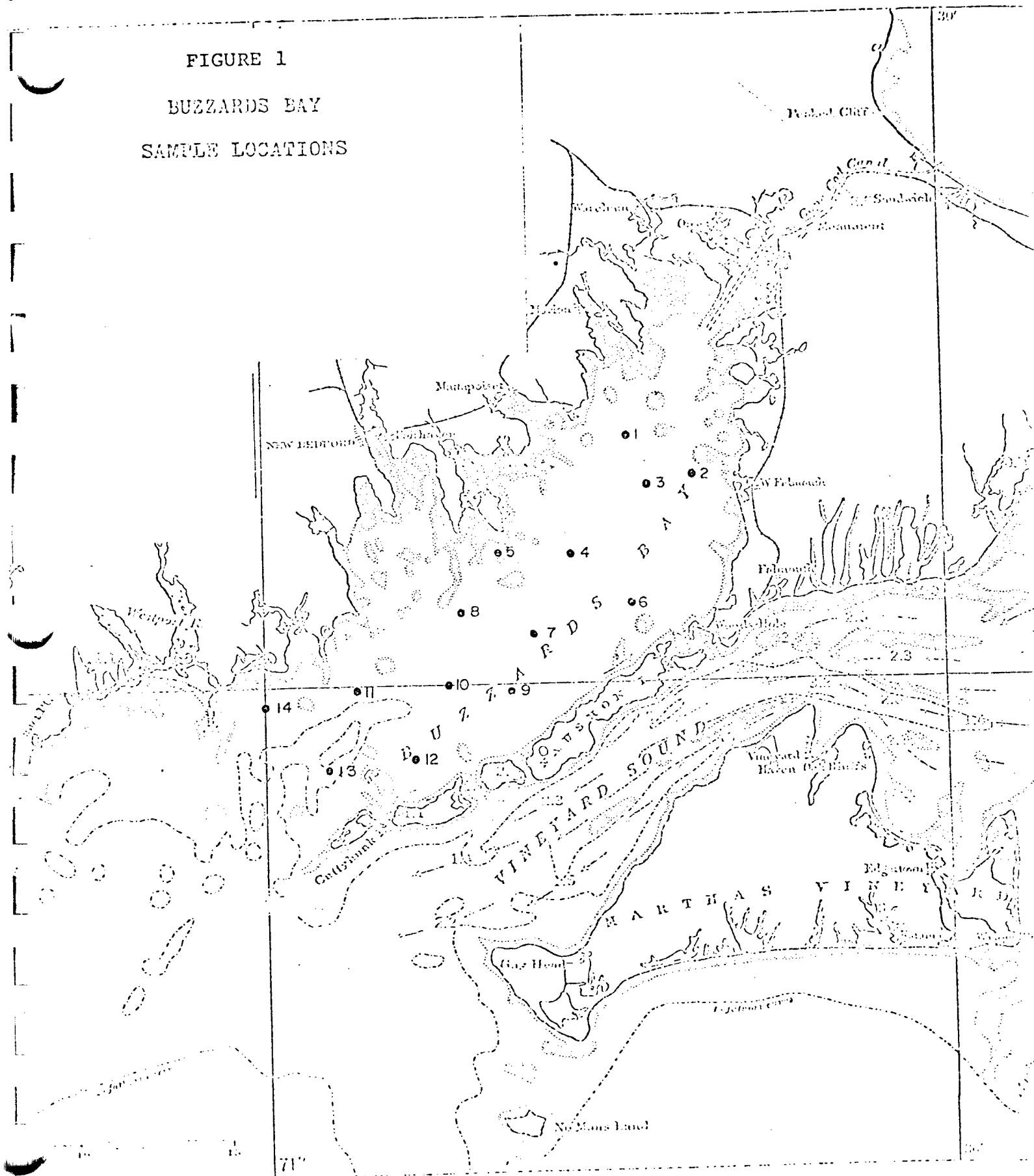


TABLE 1

WATER QUALITY ANALYSIS RESULTS

Station	Date	Time	Location	Depth/ ft.	T°C	pH	Salinity ‰	Dissolved Oxygen mg/l	Turbidity mg SiO ₂ /l
1S	29 May 73	11:23	41°37'N		13.9	7.97	31.5	6.74	2.8
B	29 May 73	11:23	70°44'W	38.0	13.2	7.91	32.5	6.91	5.6
2S	29 May 73	14:03	41°36'N		13.6	7.95	33.0	7.26	3.0
B	29 May 73	14:03	70°41'3"W	34.9	13.3	7.95	32.5	5.45	2.7
3S	29 May 73	13:05	41°36'N		13.7	8.00	33.0	6.44	3.4
B	29 May 73	13:05	70°43'W	34.9	13.3	7.98	33.5	5.46	3.2
4S	25 May 73	13:18	41°34'N		13.4	7.91	32.0	4.89	3.8
B	25 May 73	13:18	70°46'30"W	46.7	12.9	7.90	32.0	5.58	3.7
5S	22 May 73	14:29	41°33'50"N		12.9	7.93	32.0	7.20	4.0
B	22 May 73	14:29	70°50'W	29.5	13.3	7.72	33.0	6.50	2.8
6S	29 May 73	14:54	41°32'30"N		13.5	7.95	32.0	6.43	3.6
B	29 May 73	14:54	70°44'W	43.0	12.5	7.95	32.0	7.07	4.6
7S	25 May 73	11:27	41°31'33"N		12.4	7.90	31.0	6.55	3.0
B	25 May 73	11:27	70°47'53"W	49.7	11.8	7.88	31.0	7.03	3.3
8S	25 May 73	12:00	41°32'30"N		12.9	7.92	31.5	7.36	3.2
B	25 May 73	12:00	70°51'W	47.0	12.8	7.85	31.5	4.16	2.5
9S	25 May 73	10:54	41°29'30"N		11.9	7.93	30.5	7.30	2.8
B	25 May 73	10:54	70°49'W	51.6	11.8	7.90	30.5	7.01	2.3
10S	23 May 73	13:45	41°30'1"N		12.9	7.98	31.5	7.57	2.5
B	23 May 73	13:45	70°52'1"W	61.3	11.7	8.01	32.0	6.94	2.1
11S	23 May 73	12:50	41°29'45"N		12.8	7.88	31.5	7.85	2.9
B	23 May 73	12:50	70°55'41"W	62.5	12.0	7.91	32.0	7.47	2.5
12S	23 May 73	11:15	41°27'40"N		12.9	8.00	33.0	6.57	1.4
B	23 May 73	11:15	70°53'W	52.0	12.0	8.00	33.5	7.59	2.5
13S	22 May 73	11:30	41°27'30"N		12.2	7.94	31.5	8.03	3.1
B	22 May 73	11:30	70°57'1"W	91.0	11.4	7.92	32.0	8.20	1.4
14S	22 May 73	12:55	41°29'N		12.3	7.93	32.0	7.53	4.6
B	22 May 73	12:55	71°00'W	46.0	11.4	7.92	34.0	7.69	1.1

TABLE 1, Continued

Station	Total P mg/l	Chlorophyll µg/l	Coliform Counts/100 ml	NH ₃ ppb	NO ₃ ⁻ µg N/l	NO ₂ ⁻ µg N/l
1S	.017	2.6	0	161	5.75	2.87
B	.026	4.7	3	154	12.00	4.15
2S	.019	2.3	0	66	7.95	2.55
B	.019	2.7	1	147	10.30	2.55
3S	.020	2.2	1	266	6.05	3.51
B	.026	2.5	0	203	10.92	2.87
4S	.061	1.4	0	77	<0.3	1.67
B	.032	1.5	1	105	<0.3	1.67
5S	.074	4.6	14	60	9.89	1.90
B	.054	4.4	19	65	25.33	2.18
6S	.022	2.5	0	116	5.46	1.27
B	.029	2.8	4	98	6.33	5.11
7S	.058	2.6	0	77	2.58	1.67
B	.054	2.0	1	67	4.86	1.34
8S	.043	1.5	0	77	5.34	1.34
B	.044	1.8	0	63	10.17	2.34
9S	.041	3.1	0	77	6.01	0.67
B	.029	2.2	1	67	8.74	1.34
10S	.057	2.9	1	151	5.16	3.12
B	.024	2.6	1	42	3.42	3.12
11S	.032	2.5	1	56	6.90	3.12
B	.032	1.6	0	55	5.16	3.12
12S	.032	1.8	1	57	2.24	3.43
B	.030	2.3	1	55	3.85	3.12
13S	.074	3.1	1	82	20.45	2.18
B	.038	3.3	0	63	21.28	1.90
14S	.063	3.7	0	119	10.43	1.90
B	.029	3.8	4	37	16.39	1.90

surface and bottom values except at station 5B where the pH is lower than anywhere else. The dissolved oxygen values are greater than saturation at all stations except station 3B, 4S and 4B, and 8B, where they are 0.5 ppm less than saturation. Phosphates in general show higher values for the surface than for the bottom with the highest value at station 5. Station 5, which is in the Fairhaven dredge spoil area, shows higher chlorophyll and total coliform values. These higher values are probably due to outflow from the Acushnet River and New Bedford Harbor. Stations 13 and 14 show elevated phosphate levels at the surface, as well as higher chlorophyll and nitrate in surface and bottom water.

Turbidity data show no general trend, but do seem to be significantly lower than the levels reported by Rhoads.⁽⁹⁾ In a study in August 1971, he measured turbidity levels of 10-35 mg/l near station 6. When correlated with the tidal cycle, his data show turbidity maxima on the ebb tide. In the present study, values at stations 6, 7 and 9 are much lower than those given by Rhoads for waters over similar muddy sediments. Two possible explanations can be advanced for this difference. It appears from Rhoads' data that turbidity is at a minimum during the flood and high tide slack water. The samples at stations 6, 7, and 9 were taken 2.45, 2.54 and 3.1 hours before high tide. A second explanation is the possibility of large seasonal changes in bottom turbidity due to reworking by sediment feeders whose metabolic activities promote the resuspension of bottom muds.

TABLE 2

TRACE METALS IN WATER COLUMN
(ppb)

<u>Station</u>	<u>Cu</u>	<u>Zn</u>	<u>Cd</u>	<u>Pb</u>	<u>Cr</u>
1S	12.7	3.3	7.7	0.4	n.d.
B	6.2	16.4	3.2	1.05	2.8
2S	8.6	6.0	9.7	3.2	0.9
B	7.8	20.2	1.80	1.0	n.d.
3S	14.3	11.1	0.9	2.1	n.d.
B	8.6	26.4	0.62	0.9	n.d.
4S	1.44	7.0	0.66	0.9	n.d.
B	2.02	5.8	0.37	10.1	n.d.
5S	7.8	18.1	1.43	2.94	1.0
B	6.0	28.5	1.36	5.6	1.1
6S	1.07	4.32	0.20	2.09	n.d.
B	4.9	29.7	0.21	0.9	n.d.
7S	5.5	14.0	0.175	1.40	n.d.
B	1.3	4.5	1.60	0.64	n.d.
8S	8.8	18.5	1.61	2.55	n.d.
B	3.74	25.8	0.66	1.54	n.d.
9S	7.7	8.4	16.6	1.72	n.d.
B	3.56	11.2	0.61	5.94	0.6
10S	11.1	5.5	0.92	1.07	n.d.
B	1.79	5.4	0.60	0.56	n.d.
11S	9.6	25.4	0.42	1.73	n.d.
B			0.17	1.18	n.d.
12S	11.7	14.5	0.641	1.35	n.d.
B	11.4	16.0	0.43	1.27	n.d.
13S	9.2	9.5	1.04	5.21	0.5
B	5.1	7.9	0.55	4.5	0.7
14S	5.2	6.2	2.81	1.8	3.4
B	6.0	23.2	0.94	6.6	n.d.

n.d. = not detectable

Since our samples were obtained during May, a less active period for sediment dwellers, one might anticipate a difference between the present work and Rhoads' results.

C. Sediment Analyses

Analysis of the sediment samples for oil and grease, polychlorinated biphenyls (PCB's), and organic content were performed on the grab specimens. All trace metal, sulfide, and grain size data were done on core specimens except for stations 2, 5, and 14, for which we were not able to obtain core specimens. The results of oil and grease, PCB's, and organic content are given in Table 3. Stations 8, 9, and 10 are higher in oils and grease than the inner bay stations, possibly due to outflow from Fairhaven Harbor or shipping activity through the bay. Station 5 is highest in PCB's, which may be due to the dredge spoil previously dumped there or to run-off from the Acushnet and waste disposal in New Bedford Harbor.

Table 4 shows the trace metal distribution in the sediment in Buzzards Bay. Each core was analyzed at 0-5 cm from the sediment-water interface and at 20-25 cm, except station 13, which was sampled at 0-5 cm and 15-20 cm. Since stations 2, 5, and 14 did not have cores, a portion of the grab sample was used. It can be seen from the data that in general the metal content is higher in the sediments on the eastern side of the bay than on the western side, which agrees with results of Moore.⁽⁵⁾

Table 5 data presents a comparison of heavy metal data in sediments obtained in the present study with those determined by

TABLE 3

ORGANIC MATTER IN SEDIMENTS

<u>Station</u>	<u>Oil & Grease (ppm dry weight)</u>	<u>Polychlorinated Biphenyls (ppm by wt.)</u>	<u>Organic Content (% by wt.)</u>
1	88.6	0.032	6.65
2	80.1	0.113	1.58
3	90.3	0.034	1.81
4	197.9	0.274	4.54
5	110.4	0.543	3.65
6	91.4	0.226	6.72
7	157.3	0.406	6.82
8	239.8	0.077	2.39
9	226.7	0.201	4.82
10	377.5	0.175	6.13
11	159.8	0.222	5.30
12	207.4	0.242	5.81
13	620.8	0.072	1.52
14	81.4	0.079	0.88

TABLE 4

TRACE METALS IN SEDIMENT
(ppm)

<u>Station</u>	<u>Zn</u>	<u>Cu</u>	<u>Pb</u>	<u>Co</u>	<u>Cd</u>	<u>Ni</u>	<u>Cr</u>	<u>V</u>	<u>Hg</u>	<u>As</u>
1-0	69.6	14.1	41.9	4.3	0.86	22.6	35.5	107.0	1.07	n.d.
1-20	86.8	10.0	24.3	11.7	2.4	24.8	38.2	68.2	0.09	6.04
2	41.3	4.2	9.7	10.9	0.4	9.7	8.7	27.0	0.38	1.11
3-0	120.8	18.6	28.6	5.7	1.3	32.4	43.7	57.1	0.70	n.d.
3-20	100.3	6.1	1.2	8.5	1.4	17.8	29.3	64.0	0.24	n.d.
4-0	26.1	3.7	7.2	9.6	1.1	15.4	20.9	26.2	0.08	n.d.
4-20	47.2	12.4	25.3	6.0	7.2	15.8	31.7	39.6	0.23	n.d.
5	29.1	6.5	15.6	4.5	1.4	7.4	9.8	6.4	0.20	1.64
6-0	118.5	14.7	34.3	16.9	0.2	34.8	44.4	71.9	0.16	n.d.
6-20	126.1	11.5	24.6	17.0	0.3	28.0	38.6	60.7	0.11	n.d.
7-0	91.5	18.1	38.1	18.6	0.6	31.9	41.0	82.9	0.20	n.d.
7-20	70.0	10.7	23.7	8.4	1.2	23.0	31.1	60.0	0.13	n.d.
8-0	103.0	24.0	44.5	8.4	2.2	26.8	39.9	38.6	0.23	4.22
8-20	48.4	7.7	20.2	5.2	n.d.	19.2	27.5	57.8	0.12	3.83
9-0	64.4	11.5	30.3	7.5	0.9	17.1	29.0	56.1	0.11	1.35
9-20	35.5	5.4	12.6	6.0	0.8	10.0	16.9	25.5	0.07	n.d.
10-0	84.7	15.4	32.9	11.4	0.7	32.5	40.4	68.9	0.14	n.d.
10-20	79.4	10.3	22.0	11.0	2.0	22.0	38.8	50.5	0.10	n.d.
11-0	94.2	14.9	27.9	6.9	2.1	20.7	36.8	40.7	0.34	n.d.
11-20	38.5	5.7	14.9	10.4	1.2	15.7	26.7	29.5	0.12	n.d.

TABLE 4, Continued

<u>Station</u>	<u>Zn</u>	<u>Cu</u>	<u>Pb</u>	<u>Co</u>	<u>Cd</u>	<u>Ni</u>	<u>Cr</u>	<u>V</u>	<u>Hg</u>	<u>As</u>
12-0	182.8	17.0	30.7	8.5	7.2	29.8	39.6	41.3	0.20	3.79
12-20	71.6	13.3	34.6	5.6	2.4	24.5	39.0	51.9	0.11	4.46
13-0	85.7	6.6	21.5	6.0	0.8	4.1	16.1	40.0	0.51	1.55
13-15	30.4	2.4	7.7	3.2	0.3	7.2	5.4	10.1	0.12	0.07
14	64.5	15.7	10.4	9.3	0.2	13.0	12.2	11.4	0.18	0.41

n.d.= not determined

TABLE 5

MOORE VS NEA SEDIMENT DATA
(Concentration in ppm)

Sample		<u>Cr</u>	<u>Cu</u>	<u>Ni</u>	<u>Pb</u>	<u>V</u>	<u>Zn</u>
Moore #	(NEA #)						
31-33	(1)	30 (37)	14 (12)	10 (23)	33 (33)	45 (85)	65 (78)
91	(2)	17 (9)	4.2 (4.2)	6.9 (10)	16.5 (10)	36 (27)	TR (41)
10	(3)	14 (37)	3.5 (12)	5.8 (25)	5.6 (15)	30 (60)	44 (110)
43-44	(4)	34 (26)	4 (8)	22 (15)	56 (16)	80 (32)	64 (37)
25	(6)	52 (41)	15 (13)	19.6 (31)	28.5 (29)	66 (66)	46 (122)
66	(7)	71 (36)	22 (14)	25.7 (27)	82.3 (31)	72 (71)	63 (81)
73	(8)	21 (34)	4.9 (16)	5.6 (23)	16.5 (32)	32 (48)	TR (76)
71	(9)	25 (23)	5.1 (8)	9.5 (13)	14.5 (21)	43 (40)	72 (50)
119	(10)	64 (40)	15.5 (13)	24 (27)	58 (27)	70 (59)	ND (82)
81	(11)	35 (32)	8 (10)	8.7 (17)	26.3 (21)	43 (35)	TR (66)
84	(12)	16 (39)	1.6 (15)	3.5 (27)	14.0 (32)	26 (46)	31 (127)
132	(13)	41 (11)	7 (4.5)	13.4 (6)	31.5 (14)	52 (25)	55 (58)

TR= trace

ND= not determined

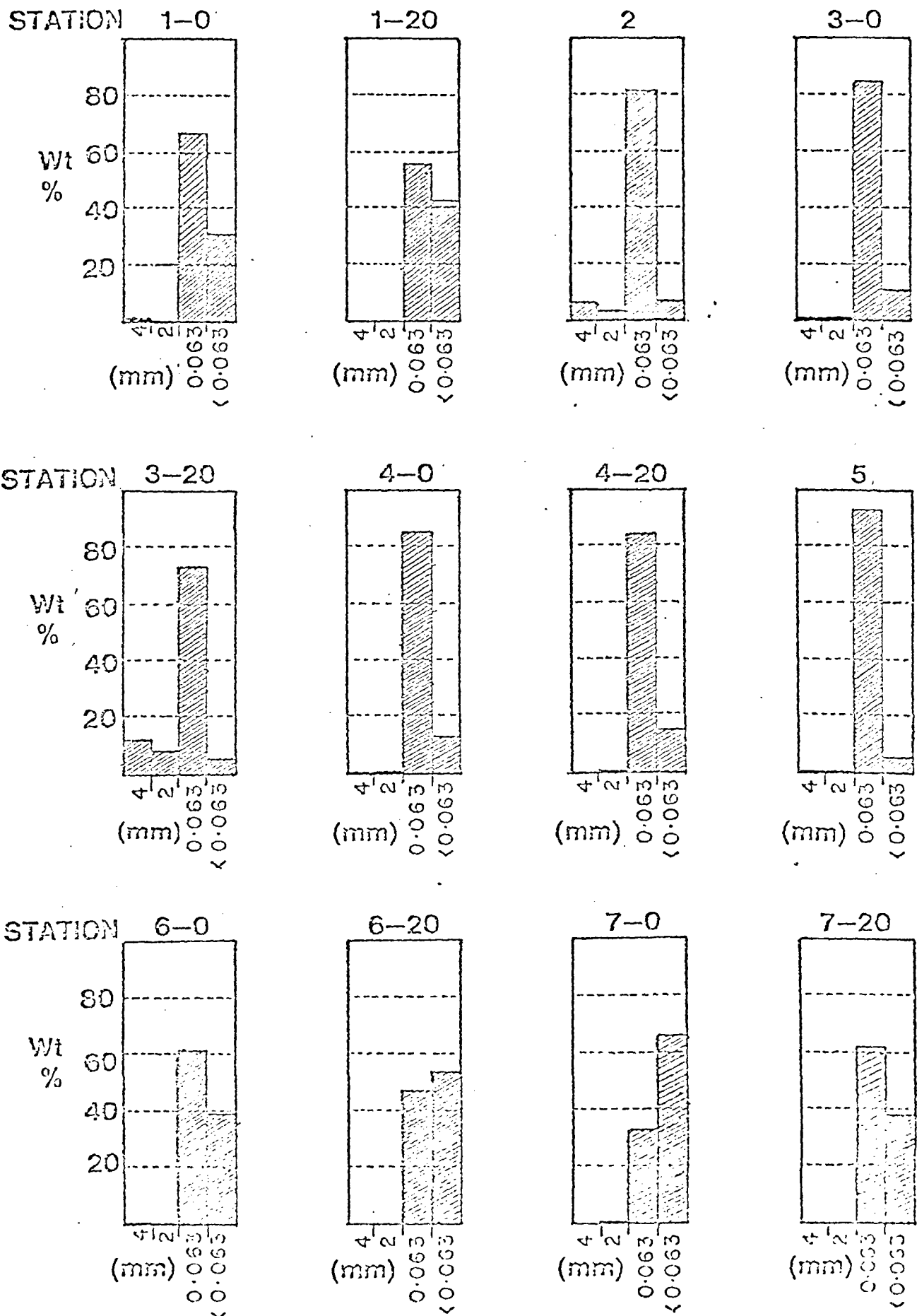
Moore at approximately the same locations and shows overall agreement except for the zinc values, which vary considerably and show no clear trend. Station 3 is about 3 times as great in all metals as the comparative station 10 of Moore's results. Station 4 is uniformly smaller than Moore's data, while station 6 is approximately the same. Station 12 is approximately 2.5 times greater than Moore's station 84. Station 13 is 2 to 3 times smaller than Moore's station 132. Station 2, which is in the middle of a disposal site, and station 3, just west of this site, have somewhat higher than average values, but at station 5, which is the dredge spoil disposal site, metal concentrations are low. The sulfide values (Table 6) show the same general trend.

Grain size distribution of the core samples is given in Figure 2. Stations 1, 2, and 3 indicate a sandy bottom, as do stations 11, 13, and 14. Correlation of grain size distribution with sulfide content shows no clear trend. However, stations 6, 7 and 10 show both elevated levels of sulfide and greater than average silt/clay fractions. Comparison of the % solids (see Table 6) in the sediment with % silt/clay fraction shows a correlation of -0.86 which indicates the greater compactness of the sediment in the sandier areas. None of the stations show the high water content in surface sediments which would indicate reworking by pellet-forming burrowing organisms. This may explain the low turbidities observed in bottom water samples. The results of our grain size analyses are in agreement with the more complete studies of Moore⁽⁵⁾ and of Hough⁽¹⁾ as shown in Figure 3.

TABLE 6

<u>STATION</u>	<u>SULFIDE (ppm)</u>	<u>% SOLIDS</u>
1-0	242	43.946
1-20	98	46.061
2	23	80.840
3-0	37	71.864
3-20	1	61.557
4-0	14	71.813
4-20	49	51.840
5	7	75.500
6-0	142	43.696
6-20	100	47.103
7-0	178	41.972
7-20	140	61.709
8-0	277	44.091
8-20	44	57.454
9-0	424	50.301
9-20	82	69.881
10-0	123	45.599
10-20	126	52.631
11-0	241	49.188
11-20	41	63.836
12-0	322	46.937
12-20	215	49.738
13-0	51	66.979
13-20	<0.1	88.770
14	17	77.249

FIGURE 2



GRAIN SIZE DISTRIBUTION OF SEDIMENTS

FIGURE 2 CONTINUED

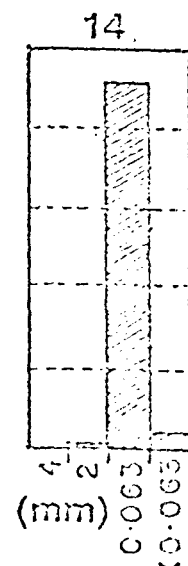
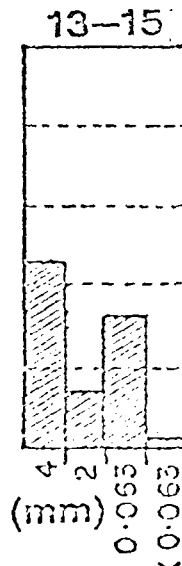
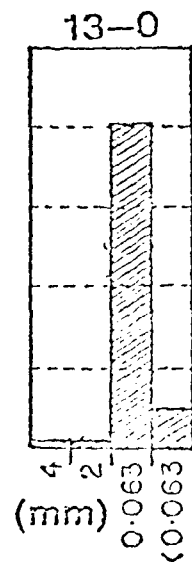
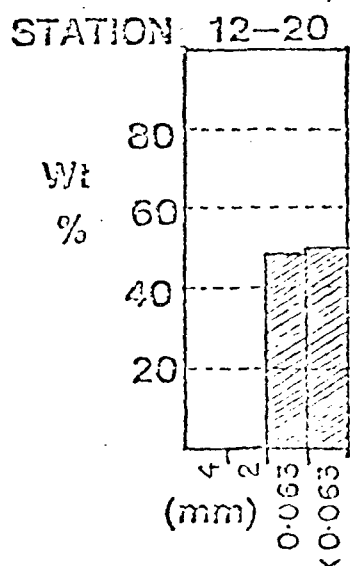
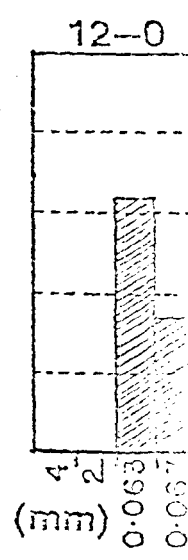
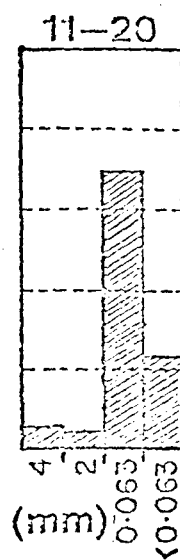
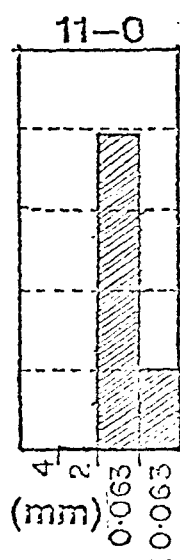
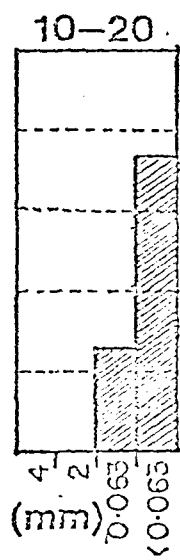
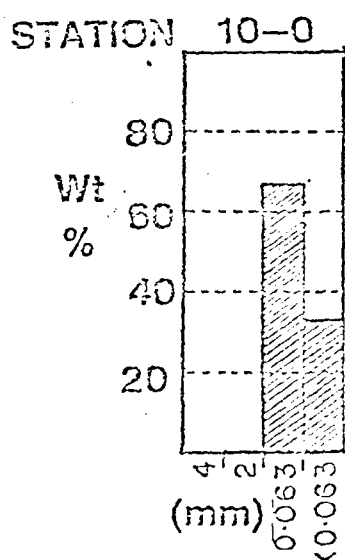
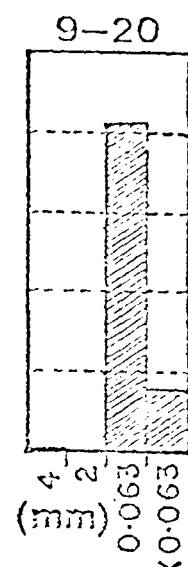
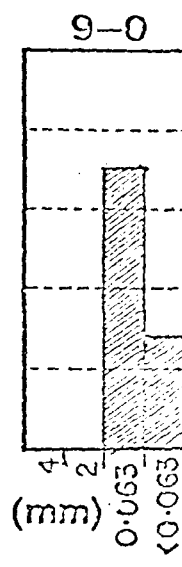
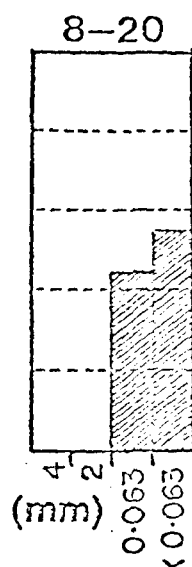
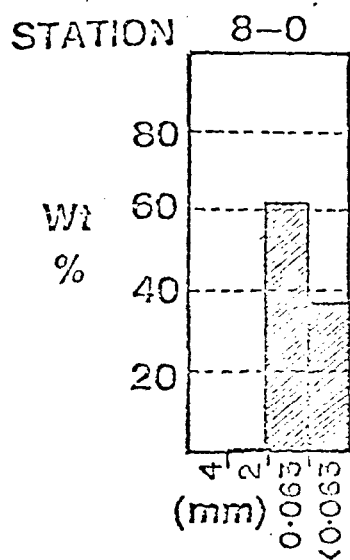
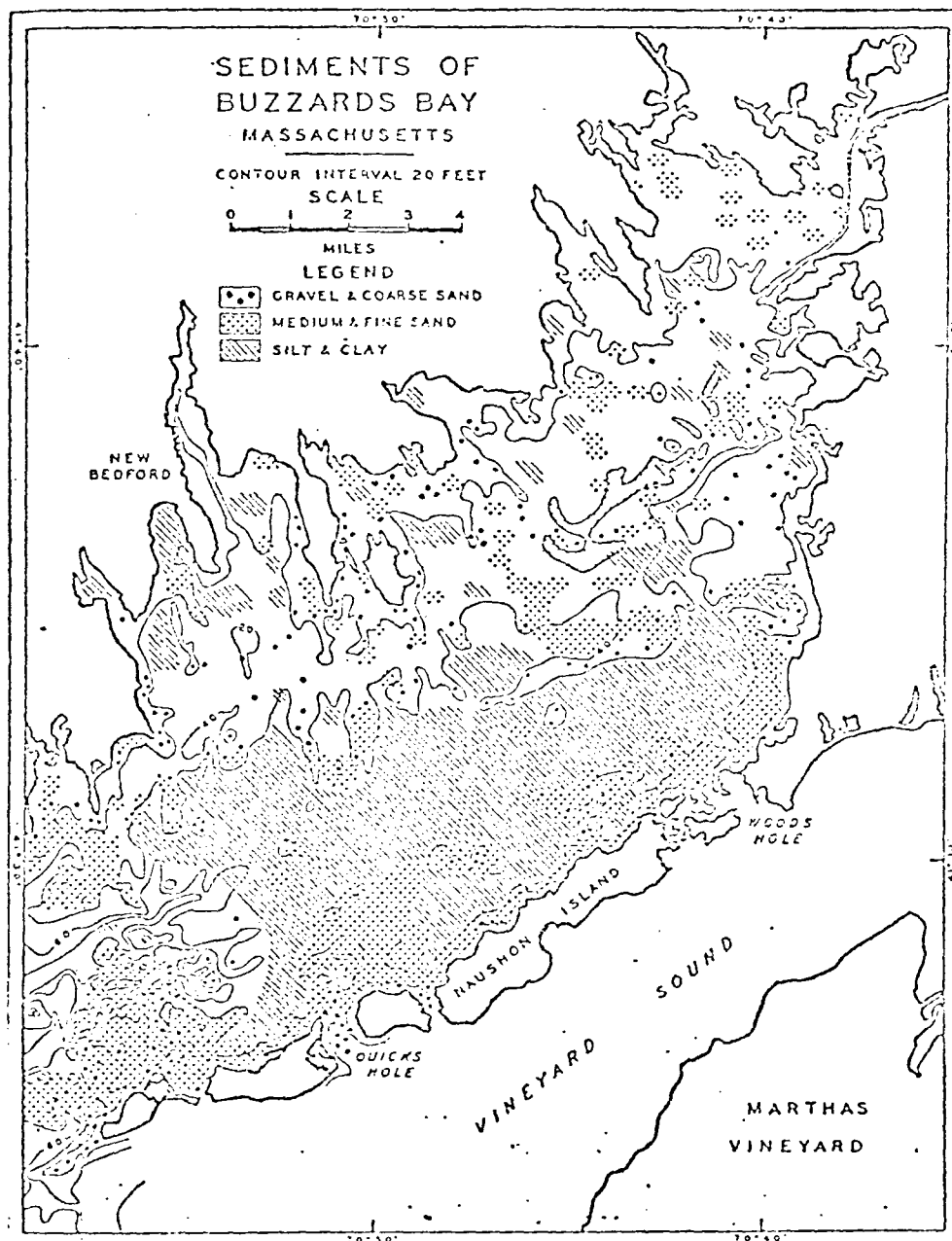


FIGURE 3



from Hough⁽¹⁾, p.21.

IV. CONCLUSIONS AND RECOMMENDATIONS

A. Selection of a Dumping Site

The process of selecting a dumping site in Buzzards Bay included the consideration of the two dumping areas which now appear on navigation charts; one just south and east of the Cape Cod Canal, the other just south of West Island near the entrance to New Bedford and Fairhaven Harbors. The samples taken in these areas show them to be poor choices for the disposal of fine grained muds from a harbor dredging operation if the objective is one of containment of the dumped spoil. Both locations are subject to relatively strong tidal currents, a fact reflected in the coarse texture of the bottom sediments. These areas therefore are more likely to contain filter feeding infauna and higher populations of epifauna, such as crabs and lobsters, which are unlikely to survive burial under the dumped spoil. Furthermore, the fine grained spoil will likely be resuspended under the influence of tidal currents, significantly increasing the turbidity of the surrounding waters, and eventually settling out in small inlets close to shore or in the center of the bay.

We have selected instead a location in the south central portion of the bay due north of Station 9 and just west of the remains of a shipwreck indicated on C&GS Chart No. 249 at 41°30'18"N, 70°48'38"W. This location is 18 km southeast of the dredge site and 1.6 km southeast of the mid-bay navigation channel. The low mean water depth is 15.8 meters (52 ft.) or

6.1 meters (20 ft.) below the dredged depth of the Cape Cod Canal. The sediment in this area is typical of the silt/clay mud covering much of the central bay area. Therefore, the fine grain dredge spoils should be hydrodynamically stable in this area. Resuspension may be largely a function of type of bottom feeding organisms which predominates the newly dumped spoil. Saila, et. al.,⁽¹²⁾ found that many of the species colonizing spoil dredged from the Providence River and dumped in Rhode Island Sound were members of the faunal population native to the surrounding bottom area. If the same phenomenon were to occur on the proposed site in Buzzards Bay, the anticipated faunal community would include the polychaete worms and primitive bivalve molluscs described by Sanders.⁽⁶⁾ If pellet forming species predominate, then reworking and resuspension of the spoil will be promoted; if mat forming tube builders colonize the spoil it will be stabilized against tidal erosion.

B. Dumping Procedure

The dump site should be about 30,000 to 40,000 square meters, for example, a circle with a radius of 100 meters. Assuming no compaction and equal distribution within the dump site this area would be covered to a nominal depth of 1.8 meters. In practice this spoil distribution could be approximated by dumping from barges positioned in a random pattern around a buoy marker at the center of the dump site. The resulting deposit would have the shape of a shallow cone, possibly with a plateau region at the center.

C. Environmental Impact

The dumping location was selected to minimize the environmental impact of the disposal operation. One such impact is the physical burial of bottom fauna. Few of the epifauna or filter feeding infauna which might be buried beneath 1-3 meters of silty mud could survive. However, with some time allowed for recovery between dumps, certain burrowing bottom feeders may reach the surface. Saila, et. al.,⁽¹²⁾ have shown that Nephtys incisa are capable of burrowing through 21 cm. of sediment in less than 24 hours and that even a filter feeding bivalve, Mulinia lateralis, can burrow that distance in a longer period of time. Their conclusion was that members of these and other species could reach the surface of dumped spoil. Moreover, the benthic community in the Station 9 area should be predominately burrowing, bottom feeding infauna. The population of epifauna is expected to be much less than in sandy bottom areas.

An often critical environmental effect of ocean dumping is an increase in the turbidity of waters in the vicinity of the dump site. Excessive turbidity can be harmful to aquatic life in four ways: by diminishing light penetration and inhibiting photosynthesis and primary productivity in the food chain; by the silting of fish gills and filter feeders' syphons; by reducing vision and so making difficult the feeding of predator fish; and by altering the temperature of deep waters. These types of ecological damage should not be significant if

dumping takes place at the proposed site. While transient elevated levels of turbidity are to be expected during dumping, there should be no long term increase in turbidity levels since the dump site is in an area of silt and clay sediments where variable but, at times, high levels of turbidity ($>10 \text{ mg SiO}_2/\text{l}$) should occur naturally. The native benthic population should readily tolerate these high turbidity levels.

Other possible environmental effects include depletion of water column oxygen and the introduction of toxic materials including heavy metals, hydrocarbons, and chlorinated pesticide compounds. Analyses of Fairhaven sediment samples show on the order of 10% organic matter (volatile solids). While relatively high, these values are not that much larger than the levels found in the center of Buzzards Bay. Around Station 9, for example, the sediments presently contain about 5% organic matter. While this level produces anoxic conditions in the sediment phase, as indicated by the high sulfide concentrations at Station 9 (424 ppm) and elsewhere, the bottom waters all contained dissolved oxygen at concentrations close to or exceeding saturation levels.

Sediment analyses in the Fairhaven samples and the 0-5 cm layer at Station 9 show similar concentration values for lead and cadmium, while mercury levels were about five times higher in the Fairhaven samples. For the first two metals there should be no enrichment at the dump site, and for mercury the increase should be small. Hexane extractable hydrocarbons (oil and grease)

in the Station 9 area range between 200 and 300 ppm, for Fairhaven samples values over 1000 times greater were measured, up to 507 ppt oil and grease. The impact of dumping such hydrocarbon rich material is not easily predicted. Blumer and others^(13,14,15) have discussed the devastating effects of oil on littoral and benthic life in Buzzards Bay due to the Falmouth oil spill. At lower sublethal concentrations, Blumer⁽¹⁶⁾ found that certain oil fractions could interfere with the chemical senses of marine animals. While detailed analysis of the Fairhaven harbor samples is required to determine the exact organic make-up of the hexane soluble fraction, it can be postulated that the material is a partially degraded, water insoluble, dense petroleum product of relatively low volatility and high molecular weight. Also, a significant portion of this product likely to be adsorbed on clay minerals. When discharged from a barge most of this material should settle to the bottom, with only a small fraction re-entering the aqueous phase.

A test of the validity of this scenario will be made by this laboratory during the next year under a contract from the Massachusetts Department of Natural Resources. Included in this study is the monitoring of water quality at the Massachusetts Bay Foul Area dumping site during disposal of dredge spoil from Boston Harbor. The material currently being dredged from the Charles River Dam site has equal or higher levels of organic material than the Fairhaven sediment.

D. When to Dump

The following proposed dumping schedule considers the impact of the dredge spoil on bottom fauna population and density as well as spawning and migration habits. With these parameters in mind, we recommend that dumping take place between 1 December and 1 March. During this interval benthic activity as well as seasonal migrations of various fish are at a minimum. This interval also predates spawning activity in the bay and so will have minimal effect on the life cycle of the embayment.

E. Alternatives

For the reasons discussed above, a contained deposit of spoil in the vicinity of Station 9 has been proposed. There are, however, at least two other modes of disposal which merit some consideration. The first is a modified dispersion dumping operation to be conducted also inside Buzzards Bay. As pointed out in the spring, 1972, Water Spectrum article,⁽¹⁷⁾ the objectives of minimum benthic population burial, maximum repopulation and maximum recycling of organic material can be achieved for small quantities of organic, non-toxic spoil if the material is widely dispersed. However, the dispersal area should be one whose physical and chemical sediment characteristics closely match those of the dredge material, to promote the survival of benthic fauna. A mode of disposal which fulfills both of these requirements is one in which barges dump as they are being moved over a large area of the south central portion of the bay.

Maximum dispersal in a pentagonal area with its corners at Stations 7, 8, 11, 12 and 9 would be a reasonable objective.

There are several drawbacks to this alternative: First, carefully supervised dumping runs are necessary so that a thin layer of spoil is laid down and so that the same area is not dumped on repeatedly. Also the environmental impact of dumped material will be more difficult to assess since the exact dumping locations will not be as well defined. Furthermore, there will be more intimate contact between spoil and the water column resulting in a higher release of heavy metals (see Table 7), hydrocarbons, and other potentially deleterious materials and the formation of a large, highly turbid cloud in the bay waters.

A second alternative would be to select a dump site outside Buzzards Bay. The closest EPA approved site for ocean dumping is located in Rhode Island Sound at 41°24'N, 71°18'W, about 51 km (28 miles) from Fairhaven Harbor. While such an operation would have the advantage of dumping on a previously designated and well studied disposal site, the complications arising from crossing state lines to dump Fairhaven spoil in Rhode Island waters may be irresolvable. Furthermore, studies in the area show only a partial recovery of the benthic community from the dumping of about 8 million m³ of dredged material from the Providence harbor area.

The nearest established disposal site in Massachusetts is located at the Boston Lightship dumping grounds, a distance of

TABLE 7

MAXIMUM INCREASE IN METAL CONCENTRATIONS OF BUZZARDS BAY WATERS DUE TO DUMPING

	Average Spoil Concentration (ppm)	Station 9 Sediment Concentration (ppm)	Average Concentration in Buzzards Bay Water (ppb)	Maximum Possible Metal Addition to the Water Column from the Spoil (ppb)
Zn	47.9	64.4	13.8	0.5 ^a
Pb	24.2	30.3	2.5	0.3
Hg	0.9	0.1	b	0.01

^a values based on the complete dissolution of all metal salts and their equal distribution throughout the bay.

^b not determined because of low concentration, expected to be about 0.01 to 0.02 ppb.

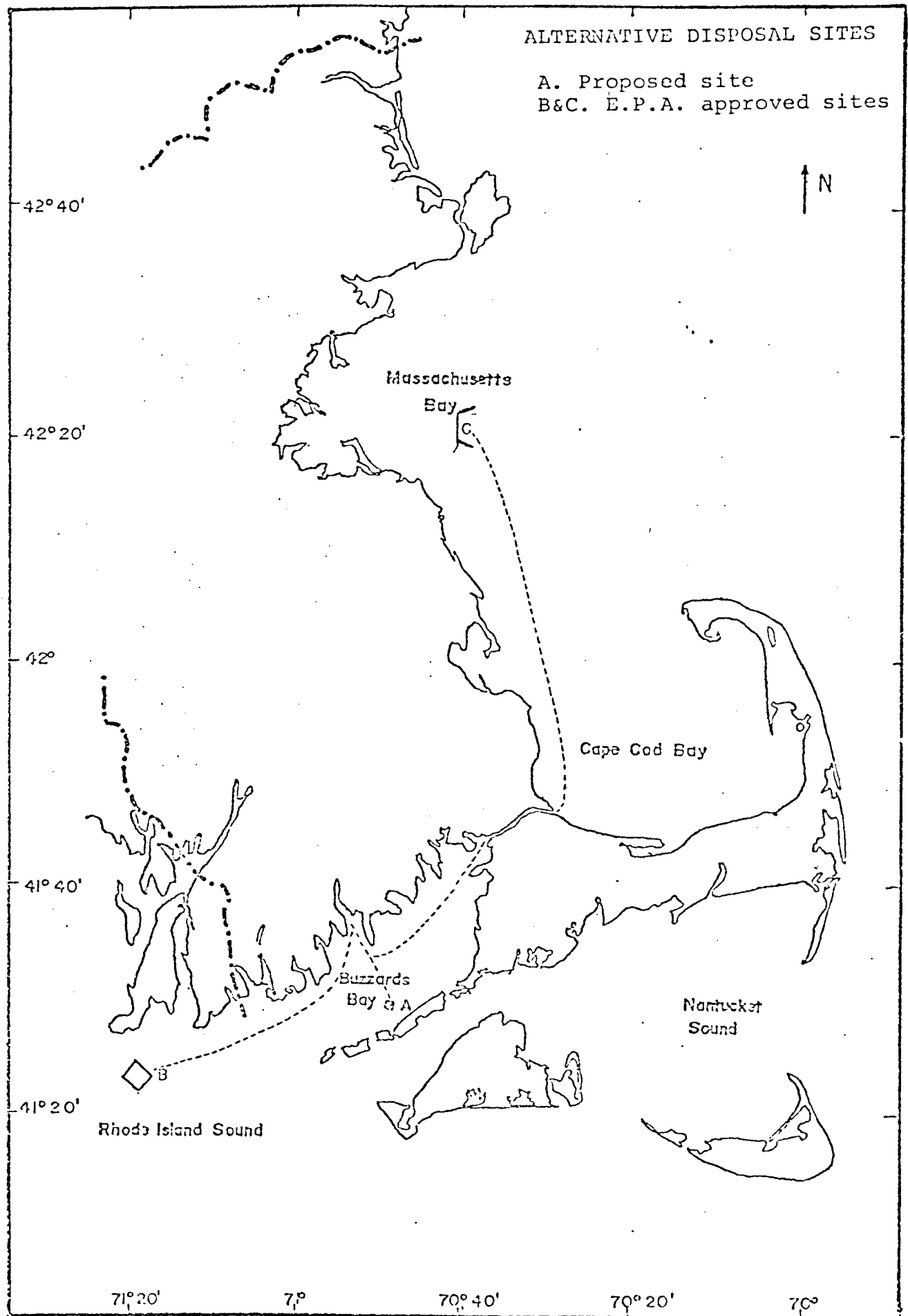
100 km from Fairhaven by a route restricted by the strong tidal currents of the Cape Cod Canal (see Figure 4).

To summarize, a site has been proposed for the disposal of 75,000 cu. yds. of dredged spoil from the Fairhaven Harbor in Buzzards Bay. The method of disposal and the most auspicious time of the year for dumping have been presented. The environmental impact of the dumping operation has been evaluated based on the data of the present work and of previous work in Buzzards Bay, and on the results of analyses carried out by the Corps of Engineers on samples of Fairhaven Harbor sediments. It should be noted that a comparison of the Corps data with the results of a 1971 state study of the New Bedford Harbor and the Acushnet River⁽¹⁸⁾ show the potential dredge materials to be considerably lower in heavy metals than other sediments in the inner harbor. While only 3 heavy metals were measured by the Corps, one may infer from their relatively small concentrations that the levels of other metals including cadmium, chromium, and arsenic are commensurately low.

Other potentially harmful substances include pesticide and petroleum residues. Although pesticide analyses were not performed, the high levels of hexane extractable material in dredge site sediments pose an undefined threat to the environment at the dump site. The availability and toxicity of these petroleum residues toward plankton and benthic organisms can only be determined through further analysis.

Finally, discussions of the proposed dumping of dredge

-32-
FIGURE 4



spoil in Buzzards Bay with members of the scientific and political communities have elicited some strongly negative reactions. Donald Rhoads' objections, stated at the Third Ocean Disposal Conference held in West Booth Bay Harbor, Maine, April, 1973, centered around the "pristine" character of the bay and the extensive study it has undergone, which may serve as a standard reference in the investigation of other coastal areas such as Long Island Sound. In fact, such studies are presently being carried out by Karl Turekian of Yale University. Several members of the Massachusetts Department of Natural Resources voiced reservations over the disposal project, alluding to the sanctuary designation of Buzzards Bay by the Commonwealth of Massachusetts and to its function as an important migration route for commercial and game fish. A public hearing on this proposal will undoubtedly bring negative response from the above individuals and also from the numerous conservation groups active in eastern Massachusetts as well as from land owners around the bay itself.

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APPENDIX 1

PROCEDURES FOR SEDIMENT ANALYSIS

Grab samples were stored and frozen in polyethylene bags. 200 gram portions were used for PCB analyses and a total of 100 grams was used for oil and grease and % organics. PCB analyses were performed by H. V. Schuster, Inc., Boston, Massachusetts, using the USDA Pesticide Analytical Manual and reported as Arochlor 1248. The hexane extraction for oil and grease was carried out using the E.P.A. procedure⁽¹⁾. The % organics were determined by the loss of volatile solids upon ignition at 550°C.

Core samples were stored frozen in their plastic liners. 5 cm. lengths of the core, about 100 grams of sample, were cut off and thawed out in an acid-washed Pyrex crystallization dish. Each sample was blended with a Teflon spatula, and 0.1 to 1 gram portions of sample were taken and analyzed for sulfide according to the procedure described in appendix 2. Then four 5 gram portions were weighed into 100 ml round bottom flasks. To three of these were made standard additions of a mixed reagent containing the ten metals listed in Table 4 and the flask walls were rinsed down with about 10 ml of distilled, deionized water (DDW), each flask attached to a reflux column with ice water running through the condenser jacket, and 12 ml of concentrated HNO_3 and 6 ml of concentrated H_2SO_4 added. The acid mixture was warmed with a powerstatted heating mantle until a steady boiling was obtained. After refluxing for 30 minutes, the heating mantles were removed and the flasks allowed to cool to room

temperature. The reflux condenser walls were washed down with DDW and the rinse caught in the sample flasks. The combined digestate was filtered through a pre-acid soaked, pre-rinsed Millipore glass fiber filter into a polypropylene flask and the digestion flask and the filterable solids were rinsed with several small portions of DDW. The filtrate and rinses were poured into 100 ml volumetric flasks and taken to volume. The reagent blank, which consisted of 12 ml HNO_3 and 6 ml H_2SO_4 in 100 ml total volume, was found to be insignificant for all metals except nickel for which a constant correction was made in all analysis results.

Analysis values of the four portions of each sample were used in a linear regression analysis with a Wang 600 programmable calculator to determine the original sample concentration. Another portion of the sample was freeze dried and from its weight loss the digested portion dry weights were calculated. All metal concentrations are expressed as parts per million of dry sample.

Besides providing the same salt matrix for samples and standards, this procedure should compensate for the loss of metals due to volatilization during digestion or adsorption during filtration and storage. Actually the nitric-sulfuric acid mixture provides a relatively mild digestion medium, boiling at about 80°C . Losses due to volatilization should therefore be minimal.

The digested samples were analyzed for zinc, copper, lead, cobalt, cadmium, nickel, chromium, and vanadium using flame

atomic absorption spectrometry. The instrument used was the Instrumentation Laboratory Inc. dual channel Model 153 in the 10 second integration mode. Samples were aspirated directly into the flame of a single slot burner. Distilled water blanks were used to give background readings between samples and also between determinations of reagent blank values. A stoichiometric air/acetylene flame was used for Zn, Cu, Pb, Co, Ni, and Cd analyses; fuel rich air/acetylene was used for chromium. Vanadium and molybdenum measurements were made using a nitrous oxide/acetylene flame.

After the AA flame analysis had been completed, the prepared sample was then used for mercury analysis. 1 ml portions of the sample were placed in a 60 ml fritted funnel, 2 ml 15% stannous chloride added, the funnel quickly stoppered and the sample purged with nitrogen at 5 ml/sec. The reduced Hg vapor was measured with a Coleman MAS-50, and the absorbance peak recorded. Calibration curves were constructed from the absorbances of the spiked samples.

A 50 ml portion of the remaining digested material, representing 1/2 the original sample was then prepared for arsenic analysis. The procedure, developed in our laboratory during the course of this contract, involved first the evaporation of the 50 ml aliquot on a hot plate until fumes of SO_3 were given off. The sample was allowed to cool and 10 ml nitric acid added and the evaporation repeated. Two more additions of nitric acid followed by evaporation were carried out. The

contents of the evaporation dish were quantitatively transferred to a 125 ml erlenmeyer flask and 0.4 ml of 40% stannous chloride and 2 ml of 15% potassium iodide were added. After standing overnight in stoppered flasks, more stannous solution was added to reduce any residual iodine formed. An apparatus for the generation of arsine, as described in Standard Methods⁽²⁾, was assembled with the 125 ml flask, fitted with a 2-hole stopper, serving as a generator. Through one hole was inserted the arsine gas delivery tube to a lead acetate scrubber and the catching solution of 4 ml of 1% silver diethyldithiocarbamate in pyridine; through the other hole was inserted a glass tube with sintered glass diffuser extending into the sample solution. This tube was connected to a regulated source of hydrogen gas. The evolution of arsine gas from the sample was effected by adding 3 gm of powdered zinc to the flask and quickly stoppering it. The self generation of hydrogen was allowed to procede for 5 minutes followed by a 25 minute purge with bottled hydrogen gas. The absorbance of the arsine-silver-diethyldithiocarbamate complex at 535 nm. was measured using a Gilford Model 240 spectrophotometer and 1 cm. path length cells.

¹ Chemistry Laboratory Manual, Bottom Sediments, Dec.1969, Environmental Protection Agency, p.42-3.

² Standard Methods for the Examination of Water and Wastewater, 13thEd.,1971, Amer. Pub. Health Assn.,p.62-64.

APPENDIX 2

DETERMINATION OF SULFIDE IN MARINE
SEDIMENTS USING A SPECIFIC ION ELECTRODE .

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Society

October 8, 1973

Boston, Massachusetts

DETERMINATION OF SULFIDE IN MARINE SEDIMENTS
USING A SPECIFIC ION ELECTRODE

I. INTRODUCTION

A. Geochemistry of Sulfur

In geological time sulfur begins life normally in the form of sulfide minerals. The common juvenile sulfur compounds include:

pyrite - FeS_2

pyrrhotite - Fe_5S_6 - $\text{Fe}_{16}\text{S}_{17}$

chalcopyrite - CuFeS_2

pentlandite - FeNiS

bornite - Cu_5FeS_2

All of these contain iron which is not surprising since, after aluminum, it is the most abundant metal in the earth's crust and also forms rather insoluble sulfide salts. Other metals of interest which occur in localized high concentrations include

sphalerite ZnS

galena PbS

cinnabar HgS

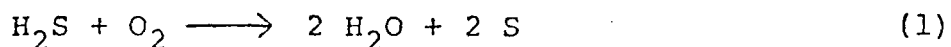
chalcocite Cu_2S

argentite Ag_2S

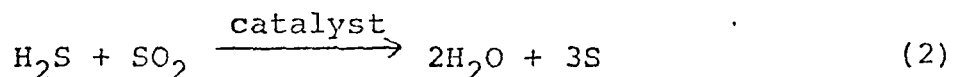
molybdenite MoS_2

Troilite, FeS , is found in meteorite and in newly formed marine sediments where it imparts a black color to the mud. Upon aging it is converted to pyrite.

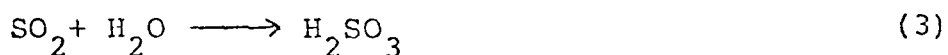
Volcanic activity introduces sulfur as the gases H_2S and SO_2 to the atmosphere. In the presence of oxygen the hydrogen sulfide is quickly oxidized to free sulfur. It may also react



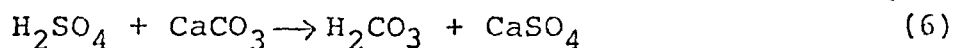
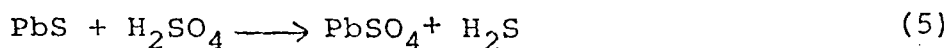
with sulfur dioxide to again yield elemental sulfur. The



catalytic action can be supplied by various metals and by water vapor. Also SO_2 is capable of being further oxidized:

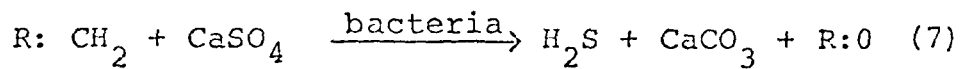


providing an important source of environmental sulfuric acid. In fact the pH of certain crater lakes and bogs is less than 3.5 because of the reactions 3 and 4. Sulfuric acid in ground water may dissolve sulfide and carbonate minerals:

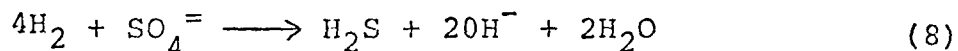


It is the reaction of the sulfate minerals which is of interest since they act as a massive reservoir of oxygen necessary for the degradation of detrital and geochemical organic matter on the ocean floor. The fossil oxygen content of sulfates in sea water and sediments has been estimated to be 50×10^{20} g compared with 12×10^{20} g of free oxygen in the atmosphere and hydrosphere.

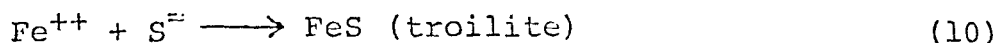
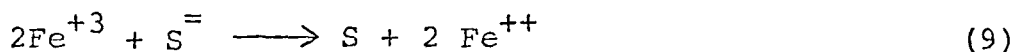
The reduction of one gram molecular weight of $\text{SO}_4^{=}$ to $\text{S}^{=}$ at S.T.P. requires 200 kcal. Plants can perform this reaction with sunlight energy. Bacteria in marine sediments oxidize carbon compounds or hydrogen from fermentation to catalyze the sulfate reduction. Bacteria of the genus Desulfovibrio are capable of the direct reduction of $\text{SO}_4^{=}$ and concomitant oxidation of organic carbon:



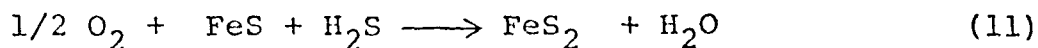
Others make use of hydrogen



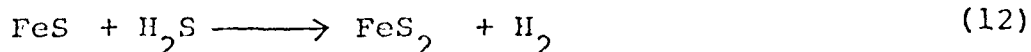
Once formed, sulfide rapidly reacts with a number of agents:



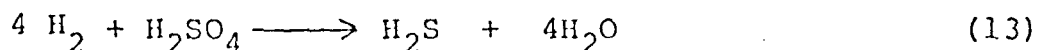
Actually the black muddy material found in Boston Harbor and other areas whose sediments contain a high organic load is hydrotroilite, $\text{FeS} \cdot n\text{H}_2\text{O}$. With aging and especially under high temperature and pressure troilite is converted to pyrite. When traces of oxygen are present reaction (11) may occur. Under



anoxic conditions pyrite is also formed, but by reaction (12)

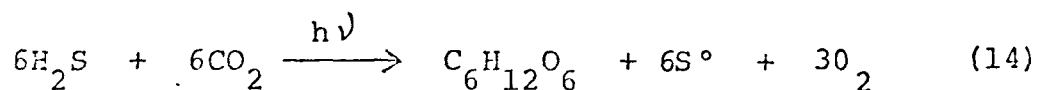


which is endothermic by 2.77 kcal. However, under microbial action one of the products is used up:



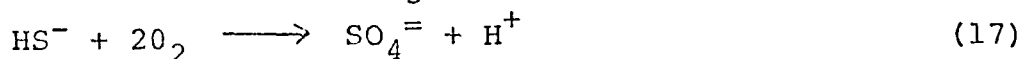
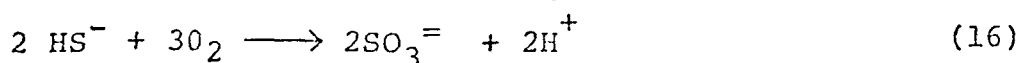
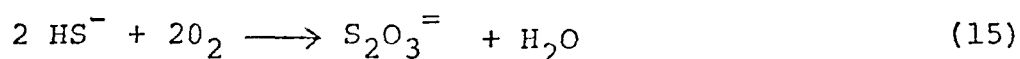
with a heat of reaction of + 73.13 kcal. ⁽¹⁾

If the aerobic layer of sediment is thin enough to allow light to pass to the anoxic layer below, purple and green bacteria may use the sulfides as hydrogen donors in photosynthesis producing free sulfur:



where the wavelength of light used by these bacteria is longer than that used by algae so the reaction can go below a thick layer of phototrophic activity.

In the presence of oxygen, sulfide is rapidly oxidized. Tests in sea water with controlled levels of O_2 and S^{2-} showed that sulfite, thiosulfate and sulfate were all products of sulfide oxidation while no elemental sulfur was detected. (2)



This last result was probably the result of working with excess



levels of oxygen and not indicative of the sulfide oxidation in sediments of low $p\text{O}_2$. In fact, Berner⁽³⁾ has proposed that the reversible half half reaction:



is the mechanism controlling platinum electrode "redox" potentials measured in many anoxic marine sediments. Intermediate polysulfide oxidation products up to S_5^{2-} are also formed reversibly.

The necessary small amounts of oxygen needed to produce a solid sulfur phase may be afforded by aeration at low tide in tidal flats, by the activity of burrowing organisms in deeper sediments, or by the action of precipitated ferric salts (equation 9).

Berner⁽³⁾ showed that for many different marine sediments there exists a linear function relating "redox" potential with the potential generated by a silver/silver sulfide electrode put directly in the sample. The electrode monitors the activity of sulfide ion which varies depending on such matrix parameters as pH, temperature and ionic strength. To gain a measure of the free sulfide concentration these parameters must be standardized preferably through the addition of an alkaline, high ionic strength buffer⁽⁴⁾.

Also of interest is the total sulfide concentration defined in Standard Methods⁽⁵⁾ as including H_2S , HS^- , $S^{=}$, as well as acid soluble sulfides. Not included in this group then are the least soluble sulfides, such as CuS , HgS and AgS .

B. Sulfide Analyses (Alternative Techniques)

The two most commonly used techniques for the analysis of sulfide in natural waters and wastes are the iodine titration and the methylene blue colorimetric method. Between these two, the iodimetric technique is the more widely applicable and the more accurate -- capable of measuring 1 mg/l. sulfide⁽⁶⁾. However, it is susceptible to several major interferences, including such sulfur compounds as sulfite, hydrosulfite and

thiosulfate and any other volatile iodine-reducing substances. Moreover, the standard procedure calls for the purging of each acidified sample with nitrogen or carbon dioxide for one hour to ensure the complete stripping of hydrogen sulfide. With such a long purge there is the likelihood of significant losses of sulfide due to oxidation by traces of O_2 in the carrier gas.

C. Silver Sulfide Electrode Characteristics

The electrode consists of an AgS membrane separating the sample and reference electrode from an internal electrolyte solution of fixed silver ion concentration. A second reference electrode is immersed in the internal silver solution.

When the electrode is placed in a test solution there is a momentary flux of mobile Ag^+ through imperfections (holes) in the AgS crystal lattice toward the solution of lower silver ion activity. The passage of positive ions sets up a potential which opposes further migration, and whose magnitude at equilibrium is a function of the activity of silver ion in the test solution. In the analysis of sulfide samples the silver ion activity is determined by the solubility product of Ag_2S . Since the lattice vacancies are specific with respect to the size, shape and charge distribution toward silver ion, the only interferences encountered arise from chemical reactions occurring at the electrode surface. For most samples the low solubility product of Ag_2S results in the probability of there being only one significant interference, Hg^{++} , in the determination of

Ag^+ and sulfide measurements should be interference-free.

The AgS membrane electrode is superior to Ag/AgS electrodes since it presents a dense, nonporous polycrystalline surface to the sample solution which is capable of rapid equilibration and it does not have a metal substrate and so is not attacked by oxidizing agents and is not sensitive to redox couples in the solution⁽⁷⁾. With the use of a portable specific ion meter the electrode can be used for on-site measurements, a distinct advantage in sulfide analyses. The principal disadvantage in specific ion analyses arises from fluctuations in the ambient temperature, whose effect can be readily calculated from the "constant" term in the Nernst Equation. Generally, in a well thermostated laboratory with samples in thermal equilibrium, a precision of about 0.2mv is obtainable. In the field, however, variability in replicate samples of 4mv is not uncommon⁽⁸⁾. For divalent ion analyses this translates into an uncertainty of 30% in direct potentiometric determinations.

The procedure described here was designed to measure sub-parts per million levels total sulfide with an inexpensive and rapid technique capable of on-site analyses of $\pm 5\%$ accuracy. The electrode procedure developed meets these criteria and is also free of the interferences which plague the iodimetric and colorimetric procedures.

II. EXPERIMENTAL

A. Sampling Apparatus

The essential components of the apparatus are a regulated source of purge gas, such as prepurified nitrogen; two Pyrex Buchner-type funnels, one of 60 cc capacity; a restricting valve to balance the purge gas flow through the funnels; and a 3-way valve to direct the gas flow. Measurements were made using the Orion silver sulfide electrode, Model 94-16, the Orion double junction reference electrode, Model 90-02-00, and the Orion portable specific ion/pH meter, Model 407. A plexiglass disk was drilled so that the two electrodes fit snugly through it (see Figure 1).

B. Reagents

About 0.01 N sulfide stock solution were prepared by dissolving 1.2 g of washed crystals of $\text{Na}_2\text{S} \cdot 9\text{H}_2\text{O}$ in 1 liter of deaerated distilled water. The 1000 ppm $\text{Cd}(\text{NO}_3)_2$ solution used was a Fisher Certified reference standard. 1 M HCl and 2 M NaOH solutions were prepared from ACS Reagent Grade chemicals. Approximately 1 liter volumes of these two solutions are continuously purged with nitrogen gas when analyses are under way.

For the comparative iodimetric tests, 2 N zinc acetate is prepared by dissolving 220 grams $\text{Zn}(\text{C}_2\text{H}_3\text{O}_2)_2 \cdot 2\text{H}_2\text{O}$ in water and diluted to one liter. 0.025 N sodium thiosulfate is prepared by dissolving 6.205 g $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$ in water and diluted to one liter. Iodine is generated in situ by the addition of 0.025 N

potassium biiodate (Fisher certified standard) to an excess of potassium iodide.

C. Procedure

Place 10 ml of 1.0 N HCl in funnel A and 20 ml of 1.0 N NaOH in funnel B, assemble the apparatus as in Figure 1, and purge both solutions with nitrogen for an additional five minutes. Turn the T valve to purge only funnel B and introduce the sample through the port in funnel A, quickly restopper it and turn the T valve so that nitrogen again passes through both solutions. Adjust the specific ion meter to measure divalent anions. When the needle comes to rest, adjust it to a convenient reference point (R) and add that volume of 1000 ppm Cd solution which is expected to decrease the sulfide concentration by about 1/2. When the needle again stabilizes, use this scale reading (S) and the volume (V) of cadmium standard added to calculate the sulfide content of the sample. For meters with conventional logarithmic scales the sulfide level in milligrams equals:

$$\frac{0.285 R V(\text{ml})}{R-S}$$

With meters such as the Orion Model 407 with a standard subtraction scale the sulfide content is more readily calculated using the formula:

$$0.285 SV(\text{ml})$$

For comparative analyses a modification of the titrimetric procedure from Standard Methods⁽⁵⁾ has been used. Sulfide is

removed from sediment samples by acid distillation with nitrogen purge. The H_2S gas is caught in 2-125 ml Erlenmeyer flasks in series, each containing 100 ml 0.2 N $Zn(Ac)_2$. The iodimetric titration for sulfide has been modified so that a known excess of iodine is generated in the acidified zinc acetate catching solution by dissolving 1 gram of potassium iodide and adding 1.00 ml of 0.025 N potassium biiodate. The excess iodine is titrated with 0.025 N sodium thiosulfate using a Gilmont 2 ml micropipette.

III. RESULTS AND DISCUSSION

Sulfide analyses, especially at low concentrations, are complicated by the oxidation of $S^{=}$ by traces of oxygen. The apparatus in Figure 1 has been designed to alleviate sulfide oxidation through the use of fritted funnels which enable the efficient purging of the two solutions with nitrogen and by minimizing the reaeration of the solution in funnel B with a snugly fitted plexiglass cover. The use of fritted funnel A to contain the acidic sulfide generating solution provides an efficient means of scrubbing H_2S from sediment samples. With a nitrogen sparging rate of 2.5 cc/sec, the sulfide from samples weighing up to 5 grams is purged out and caught in the base in about 2-3 minutes.

Since there is a significant hydrogen chloride vapor pressure in 1 M HCl solution, some sparging of HCl into funnel B will occur. For purging times as long as 20 minutes the

lowering of the pH in solution B is not enough to cause a detectable reduction in the activity of $S^{=}$ due to the formation HS^- .

The size of funnel B is dictated by the size of the two electrodes and the geometry of their holder. About 20 ml of base solution is a sufficient volume to immerse the sensing elements of the electrodes and also provide for quantitative scrubbing of H_2S from the nitrogen gas stream eluting from funnel A. The dimensions of funnel A are not critical. The system could be modified to analyze large volumes of natural water samples by replacing funnel A with a gas washing bottle, for example a tall form Drechsel type, fitted with a glass frit gas dispersion tube. Preliminary sea water analyses have been conducted using a 1 liter filter flask with a coarse dispersion tube about 3 cm above the bottom. About 85% of a $10\mu g S^{=}$ spike has been recovered from a 1 liter sea water sample, spiked with 5 cc of treated 12 M hydrochloric acid, in 15 minutes with a nitrogen purge rate of 10 cc/sec.

With further refinements, including minimizing dead space volume of the sample container and optimizing the nitrogen purge flow rate, rapid and precise sulfide analyses at the parts per billion level should be attainable.

To delineate the useful working range of the electrode and sampling system, the electrode response to varying additions of sodium sulfide solution to funnel A was monitored using the expanded millivolt scale. The results of this study, plotted

in Figure 2, show the electrode response to be linear and Nernstian above 10^{-5} M $S^{=}$. The non-linear response below about 7×10^{-6} M is probably due to the oxidation of a significant amount of the sulfide in solution by traces of oxygen before the electrode has reached equilibrium. Since the sulfide electrode comes to equilibrium more slowly at lower sulfide concentrations, the likelihood of significant oxidation of the sample is increased. The use of the system is effectively limited to concentrations $> 7 \times 10^{-6}$ M. In about 20 ml of sodium hydroxide catching solution, this concentration corresponds to 4 μ g sulfide.

To determine whether the non-linear electrode behavior at low sulfide concentrations is in fact due to traces of oxygen in the purge gas, the rate of loss of sulfide activity was monitored in 2 M sodium hydroxide purged with nitrogen, in SAOB* purged with nitrogen and in 2 M sodium hydroxide purged with hydrogen. After assembling the apparatus shown in Figure 1 and purging the system with the gas of choice, 2 μ l of sodium sulfide stock solution were added to the contents of funnel B making the initial sulfide concentration 3×10^{-7} M. When the electrode had reached equilibrium the meter needle was adjusted to mid-scale and the decrease in sulfide activity with time was recorded using values from the logarithmic standard subtraction scale. These decay curves were fitted to equations

* SAOB = Standard Antioxidant Buffer prepared by dissolving 320 g. sodium salicylate, 80 g. sodium hydroxide and 72 g. ascorbic acid in distilled deionized water to a total volume of 1 liter.

of the form $y = a e^{bt}$ where y is the scale reading observed at time t . After solving for the constants "a" and "b" with the aid of a Wang programmable calculator, the half lives of the sulfide additions were calculated (see Table 1). These results, which show the sulfide considerably longer lived in base purged hydrogen, are believed to be due to the much lower levels of trace oxygen present in compressed hydrogen. For routine analyses nitrogen was used, since the somewhat lower measurement range obtained with a hydrogen purge is offset by the hazards it presents when working in poorly ventilated areas.

An alternative explanation for the non-linear electrode response might be that trace metals could be present at $\sim 10^{-5}$ to 10^{-6} M in the base solution which would precipitate the same concentrations of sulfide. However, if this were a significant factor in electrode behavior then 0.2 M NaOH should give a curve which is Nernstian for at least order of magnitude lower sulfide concentration than 2 M NaOH. Actually the two solutions give very similarly appearing calibration curves.

Because of the instability of sulfide solutions, the preparation of a standard potentiometric curve for these analyses would require several steps. The sulfide solution must first be standardized against a stable reference solution and then used to construct a calibration curve of electrode potential vs sulfide concentration. Also, the volume of base added to funnel B would have to be accurately measured.

However, by the standard subtraction method the volume

in funnel 3 need not be measured accurately since the addition of cadmium precipitates a known portion of the total sulfide in solution. This procedure also eliminates the need for a sulfide standard and the construction of calibration curves. A wide change in sulfide concentration from one sample to the next is easily accommodated since the initial reading is arbitrarily adjusted on scale.

The accuracy of the method was evaluated by analyzing a series of sediment samples and comparing these results with those obtained using the modified iodimetric procedure. While the two methods give comparable results (see Table 2), the iodimetric analysis is more time consuming and less precise. The considerable error found in the iodimetric analysis of the third sample indicates that the result is close to the detection limit of the method.

To study the stability of sulfide in anoxic sediments the Aquarium Dock sample was analyzed within 1 hour of collection. Portions of it were placed in polyethylene beakers which were covered with Parafilm and stored at -15°C . Samples were thawed and analyzed after 1, 6 and 14 days. There was no significant loss of sulfide from any of the frozen samples. Samples stored for several months in this manner do show signs of air oxidation including the formation of a green layer in the sample closest to container walls, indicating the oxidation of ferrous sulfide.

In summary, the method provides a sensitive and precise

means of measuring the total acid soluble sulfide in sediments. Sample handling is minimal and only 3 reagents are required, of which one is the commercially available Cd standard and the preparation of the other two need not be precise. The technique is free from the interferences which affect spectrophotometric and iodimetric analyses. Those precipitated sulfides, such as HgS and CuS, which do not readily dissolve in hydrochloric acid will not be detected, but these represent a small fraction of total sulfide in most sediments.

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TABLE 1
STABILITY OF DILUTE SULFIDE SOLUTIONS

	2M NaOH with N ₂ purge	SAOB with N ₂ purge	2M NaOH with H ₂ purge
[S ⁼] (M) added	3 x 10 ⁻⁷	3 x 10 ⁻⁷	3 x 10 ⁻⁷
Half Life ¹ (min.)	8	11	25

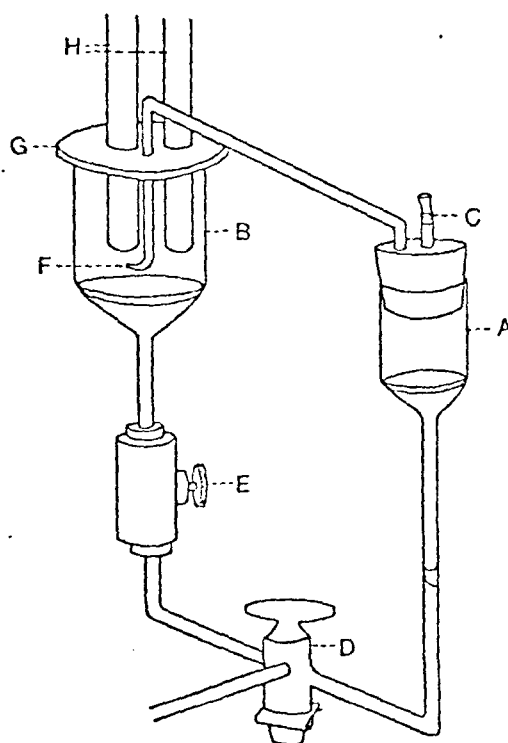
¹From linear regression solution of the form $y = ae^{bt}$

TABLE 2

METHOD ACCURACY

<u>Sample</u> <u>Description</u>	<u>Weight (g)</u>	<u>Sulfide Concentration</u> <u>(parts per million)</u>	
		<u>Iodimetric Method</u>	<u>Electrode Method</u>
Off New England Aquarium Dock, 2/1/73	0.15	2300 \pm 250 ¹	2150 \pm 70
Bird Island Flats, Boston Harbor, 2/5/73	0.2	810 \pm 20	810 \pm 21
Buoy "BWNC", Broad Sound, 2/1/73	5.	1.2 \pm 1.0	1.14 \pm 0.11

¹Error estimates are standard deviation values for triplicate analyses.



- A- 30 cc. F-fritted funnel
- B- 60 cc. M-fritted funnel
- C- Sampling port
- D- N₂ 3-way valve
- E- N₂ restricting valve
- F- Pyrex delivery tube
- G- Plexiglass cover
- H- S⁼ and ref. electrodes

FIGURE 1

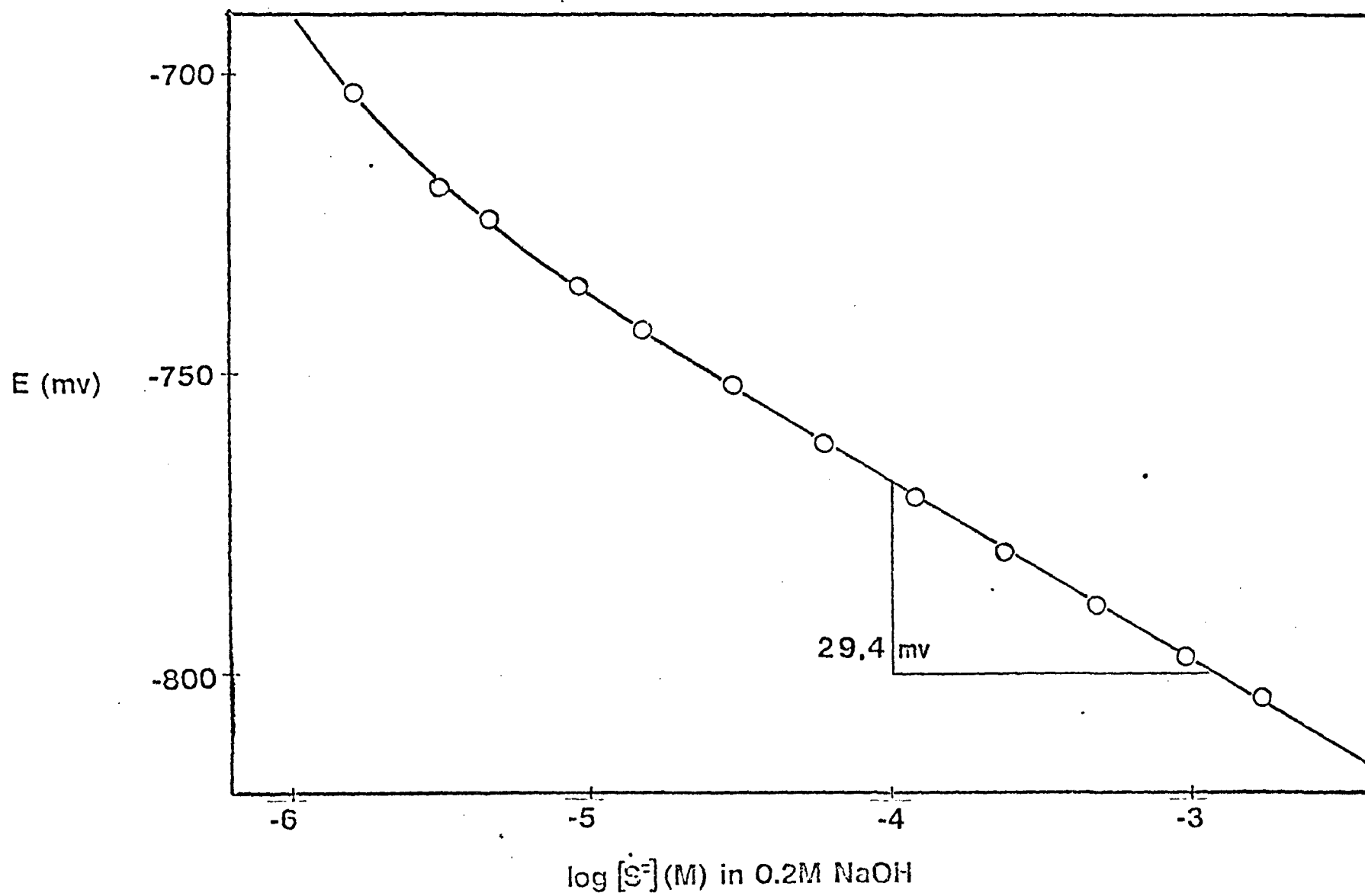


FIGURE 2

APPENDIX 3

CRITERIA FOR THE SELECTION OF DISPOSAL SITES AT SEA

On the following pages is an abstract prepared by Guy C. McLeod, Director of Research, New England Aquarium, from the manuscript "A Proposal for the Establishment of Criteria for the Selection of Disposal Sites at Sea", by Richard H. Maehl of the Research Department. The original manuscript was presented to a Corps of Engineers study group on ocean disposal in December, 1972.

Criteria for the Selection of Disposal Sites at Sea

Necessity

Nec to predict fate of materials dumped, and to predict the changes produced in the environment by these dumpings.

Important Distinctions

The near shore region has received virtually all the marine waste disposal of the past and the economics of transporting waste materials will insure that this continues. The region constitutes a small fraction of the area of the ocean, and because it is generally shallow as well, an even smaller fraction of the volume. But can rapid mixing be invoked to dilute and disperse away these wastes. Net transport of bottom sediments in an on-shore direction has been noted, and long shore currents are common keeping dissolved and suspended material near the coasts and in relatively high concentrations. Finally, this same near shore region is the site of most important fisheries and recreational uses as well as being nearest to the concentrations of population.

A second distinction must be made in the aim of a particular dumping. Is the goal a dispersion of material with dilution serving to protect the environment? Or is it imperative to contain the material at a given site to allow slow degradation or even dissolution to take place? The choice of dispersion or containment, of course, determines very different criteria for site selection.

Parameters

(1) Immediate fate of the materials and their introduction into various areas of the marine environment. This is the domain of hydrodynamics and it is proposed to build on the relatively strong theoretical base available and to utilize some existing field measurements. This should provide the means of

(a) Predicting physical effects on the environment (e.g. changes due to sedimentation, and turbidity) and the distribution of biological and chemical pollutants already in the liquid or dissolved state.

(b) Prediction of the distribution of solid sources of chemical pollution.

(2) Concentrations of chemical pollutants, including in many cases the rates at which these are being introduced (or removed) by non-biological processes. The working definition of "pollutants" will here include nutrients. The considerable body of knowledge of solubility constants, corrosion rates, and stability constants of complexions will provide a good beginning while complexation with organics will need investigation.

(3) Response of the biota to the above considered changes in the environment will be considered. Every attempt will be made to estimate effects not yet investigated by extrapolation along lines of biological similarity and along lines of chemical similarity. Subsequently, those areas most in need of direct investigations will be identified and the requisite studies outlined.

Parameters (cont)

Since it is the changes in the environment that are of concern the proposed site must be characterized in terms of the concentrations of the same substances before any waste is added. Further, this must be done for both the waters and the bottom sediments.

Interactions

While the sheer number of parameters begins to suggest the enormous scope of the problem, it is the interactions among them that introduce its real complexity. Consider a single "pollutant" added to the marine system by dumping. Some of this substance enters already in solution but some is tied up in a solid which will dissolve with time in sea water. Just in order to predict the concentrations of X the fate of both liquid and solid fractions of the dumping must be determined. Then the rate of dissolution of X must be estimated, and the fate of that fluid fraction. If substance X is a metallic element then throughout its history the concentrations of its various forms must be considered: simple hydrated ion, ion pair, inorganic complex ions, and organic complexes which in turn depend upon concentrations of various organic pollutants.

The incorporation of and physiological reaction to the metal depends on its form. Hence not total concentration but concentration of specific forms is the parameter of importance.

Substance X will also accumulate in the bottom sediments directly by adsorption and/or precipitation as well as indirectly with the remains of organisms, from which it will be extracted by filter feeders. The extent to which substance X adversely affects a given species in turn has further effects.

Purpose

The purpose of the studies is to provide a yardstick to insure that such individual studies are sufficient, to provide them with and expand the currently available data concentrating on key areas that are of the most general value and applicability, and to lay out guidelines for the actual measurements and experiments necessary.

The general format of the report to result from the proposed study is that of a manual to serve as complete guide as now possible to the evaluation of a proposed discharge of waste at sea. The manual type report will begin with the topic of waste material characterization followed by site characterization. Then will follow the predictive portions: Hydrodynamic, or transport, prediction will be covered first, followed by physical and chemical parameters and, finally, biological effects.

(1) Characterization of Waste Materials

Materials currently being dumped at sea can be placed in four major categories:

- i. industrial wastes
- ii. dredge spoils
- iii. sewage sludge
- iv. municipal refuse (baled or incinerated)

Industrial wastes and municipal refuse are examples of cases where containment rather than dispersion should be the goal of a marine disposal plan. The chemical aspects of the problem center around the rate of corrosion of containers both in terms of time until failure of the container and as a source of heavy metals. The corrosion rates of copper alloys and steels decrease with a decrease in the oxygen concentration of sea water while the corrosion rate of most aluminum alloys increased with decreasing oxygen concentration. These data suggest that oxide formation is part of the corrosion process at depth and the difference in behavior among the metals is due to the formation of protective oxides (e.g. Al) or non-protective oxides (e.g. Cu and Fe). Dissolution is also clearly present.

For an order of magnitude calculation example consider Cu or Zn. Each square meter of metal surface yields 100-200 gram which requires a volume of $1 \times 10^5 \text{ m}^3$ of seawater to keep the increase in concentration to 1-2ppb. If only this square meter of metal surface is assumed to be flushed by 1 m^2 of water, then a column $1 \times 10^5 \text{ m}$ long must flow by within the time period of one year. This would require a bottom current of approximately 0.07 knot, a reasonably small value.

The rate of introduction from the metallic components of refuse can be determined using the approaches and data introduced under Industrial Wastes. Using Zn as an example, one can assume half of this is present as galvanized coatings. Weight loss data predicts that all of this zinc will have been lost to the sea water in less than a year. Thus for each ton of baled refuse or the ash from the incineration of one ton of refuse there is introduced from this source alone 1 kg of Zn. This requires a water volume of $1.2 \times 10^6 \text{ m}^3$ to reduce to a concentration of 1 ppb.

To view this in terms of flowing water, assume a cross section of 1 m^2 for a bale of municipal waste. A column of water $1.2 \times 10^6 \text{ m}$ long with a 1 m^2 cross section must flow past this bale within the time period of dissolving to keep the increase in concentration of zinc down to 1 ppb. If the time period is one year, then a bottom current of 0.8 knot is required. This is too fast for some of the continental rise sites proposed. These calculations assume that each square meter of water perpendicular to the current direction is occupied by only one such ton or the incinerated residue of a ton of refuse. That condition would only hold true for a relatively dispersed array of wastes.

Dredging operations introduce several unique factors. While all types of chemical pollutants are possible, requiring extensive analysis, the bulk of the material will be natural sediments. Therefore it is necessary to distinguish, in the case of heavy metal contents, that portion not "permanently" tied up in e.g. silicate minerals. In addition to the extensive analysis program, of equal concern, is the sampling

which precedes it. Any exterior dredging program will involve considerable variation in material laterally and particularly vertically. Coring, to the full depth of dredging, with sampling throughout the length of the cores will be necessary to estimate total masses of pollutants involved.

Grain size analysis is another important parameter in dredged spoils.

(2) Site Description

Not merely the immediate site of waste discharge, but the entire region to be affected by the subsequent transport of waste must be described in terms of those chemical constituents to be added or that display synergistic effects with those to be added, grain size composition, and, of course, the biota present. For these parameters best methods have been compiled along with acceptable sampling procedures, utilizing correlations among constituents to reduce the analytical requirements wherever possible.

For the determination of hydrodynamic and some physical variables (e.g. currents, turbidity, ambient temperature, and water density profiles) time dependence is critical and appropriate sampling strategy as well as measurement methods will be developed. In those areas where rapid dispersion of the discharged waste is expected, for example, seasonal correspondence between sampling and dumping must be assured. Where long term dispersion will occur nothing less than mean annual values will suffice. The duration of thermoclines must always be considered in cases of continued discharge and its presence or absence during the particular time of short term discharges be determined.

(3) Hydrodynamics

The first stages of the predicted transport of wastes discharged at sea (e.g. convective descent) are susceptible to theoretical treatment. Methods for the determination of the eddy diffusion coefficients are also available and would be included.

The problem of the nature, and even the existence, of a "collapse" phase, on the other hand, requires some original work. The goal of this effort would be an empirical expression capable of predicting the extent of the collapse phase in discharges so that the starting point for the long term dispersion can be satisfactorily estimated.

Long term dispersion was seen to be amenable to theoretical treatments and these will be included along with the conditions necessary to meet their governing assumptions.

The question of bottom transport and resuspension is intimately related to the physical parameters of turbidity and sediment character. It is expected that the work of others, e.g. Sayin, will provide the necessary work on the subject of turbidity, per se. From the viewpoint of transportation of sediments along the bottom, existing theoretical

treatments of the topic will be extended to consider the rate of material transport.

(4) Physics

The subject of temperature has been included under Material and Site Characterizations, while turbidity and sediment character have been treated under both Site Characterization and the bottom transport and resuspension subdivision of Hydrodynamics.

(5) Chemistry

In addition to analysis and sampling studies work on reaction rates from the point of view of durability of containers for retention of wastes and rate of introduction of pollutants is imperative. Additional experimental work is proposed in the areas of controlling parameters and corrosion mechanism. The former includes the important rate effects of temperature while both areas deal with the role of dissolved oxygen in attacking metals and determining the dissolved products.

After analysis of any type of waste, there arises the questions of description from any solids present and formation of particular ionic species in solution. These will be examined specifically for the case of sea water utilizing examples of three of the major types of waste.

(6) Biological

The biological investigations needed for a complete treatment of the marine disposal of wastes are enormous. Clearly a few key areas must be selected for work that will be broad in their applicability.

- (a) The effect of a suddenly imposed marine environment on several species of terrestrial bacteria that are normally important in degradation of wastes. (and marine bacteria)
- (b) Toxicity of selected components to different trophic levels.
- (c) Studies to establish the quantitative relationship between the concentration in sea water of some substance and the subsequent concentrations of this substance in the food chain.

APPENDIX 4

CONTRACT WORK STATEMENT

4. CONTRACTOR SERVICES.

The contractor shall perform all work required to accomplish the intent of this contract and, as part of such work, shall perform the following specific services:

a. Criteria. Inasmuch as criteria for disposal site selection are only in the formative stage of development, pages 17-21 of an article in the Spring 1972 edition of Water Spectrum, Vol. 4, No. 1, published by Office, Chief of Engineers, entitled, "Dredging Disposal", is furnished the contractor to serve as a "state of the art" basis for the contractor's consideration and evaluation. Laboratory analyses shall equal or exceed accuracy requirements of Standard Methods, A.P.H.A. Field observations shall meet minimum quality standards of USN, H.O. Pub. 607, Instruction Manual for Obtaining Oceanographic Data.

b. Coordination. It is anticipated that a similar site selection study in Penobscot Bay, Maine, will be conducted by others concurrent with this study. The contractor will be expected to exchange freely his ideas relative to his work with those of his counterpart on the correlative study, after initiation of the other contract, for the purpose of site selection criteria evaluation and mutual assistance.

c. Literature Survey. The contractor shall conduct a literature survey of the existing data base on currents and benthic communities in Buzzards Bay which will serve as a basis for determining the extent of additional general field sampling and current observations required to complete this contract.

d. Field Work. A series of sites shall be selected for field sampling of benthos, sediments and the water column. The Government will supply grab samples and cores as required by the contractor. Turbidity observations or serial suspended sediment samples shall be taken for correlation with concurrent observations by others in the Rhode Island Sound, Buzzards Bay mouth, to establish a data base for evaluating turbidity background which can be related to possible additional turbidity caused by dumping at the selected site. These observations shall be performed by the contractor on a vessel furnished by the contractor under this contract.

e. Laboratory Work. A series of laboratory analyses shall be made of water quality parameters, including turbidity, trace metals (mercury, lead, zinc, cobalt, copper, chromium, and arsenic), sedimentary quality and size distribution analyses, indications of residual petroleum products, and PCB's. Metals shall be analyzed in the water column as well as in cores obtained in selected sites.

f. Report. A report shall be submitted in triplicate, indicating the site most favored for dumping from the standpoint of producing least ecological damage. It shall set forth the reasons for the selection, including data backup, and shall describe in detail the rationale used in arriving at the selected site. All data obtained in the study shall be submitted with the report including site plans showing sampling and collection stations.

Also included shall be an opinion of the ecological effects of the disposal of improvement dredging materials from Fairhaven Harbor based on sediment analyses to be furnished by the Government on the disposal ground and on the surrounding ocean area. Above all, the report shall discuss ocean disposal criteria as they relate to the Water Spectrum article and the contractor's interactions with the investigator engaged in the correlative study of Penobscot Bay with the view of advancing the present stage of ocean disposal site criteria development.

63

Quahog

PCBs IN CLAMS (*MERCENARIA MERCENARIA*) FROM THE NEW BEDFORD HARBOR,

RECEIVED
MASSACHUSETTS AREA

FEB 19 1980

*Woods Hole
Alfred
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ABSTRACT

PCB concentrations in clams (*Mercenaria mercenaria*) and oysters (*Crassostrea virginica*) from 17 stations of the western and New Bedford Harbor areas of Buzzards Bay, Massachusetts clearly show that the New Bedford Harbor area is severely polluted with up to 5 ppm dry weight of PCBs. The most likely sources of the PCB input are chronic releases from two electrical component manufacturers in New Bedford. A close proximity of the shellfish to the source of input is indicated by the high relative abundance of the di-, tri-, and tetrachlorobiphenyls. The data suggest that the New Bedford Harbor area should be considered along with the Hudson River and Chesapeake Bay as one of the major sources of PCB inputs to the northeastern U. S. coastal area.

INTRODUCTION

Following Jensen's (1) report identifying polychlorinated biphenyls (PCBs) in organisms inhabiting Swedish waters, there emerged with each succeeding year further evidence of worldwide contamination (2). Although recent legislative action (Toxic Substance Control Act, 1976) will restrict further contamination, the toxicity of these compounds in conjunction with their resistance to environmental degradation (3) requires that their proximate and long-term effects on marine life be examined; and that their distribution and movement through the environment be continuously monitored. Of particular concern are coastal areas where commercial and recreational shellfishing and fishing, in benthic environments known to possess hazardous levels of PCBs, may result in human consumption of contaminated organisms.

The presence of two large electrical component manufacturing facilities engaged in the use and discharge of PCBs combined with the existence of a local fishery suggested the importance of studying the distribution and accumulation of PCBs in the New Bedford, Massachusetts area. This study employed one of the edible clams, *Mercenaria mercenaria* (L.) as an indicator for several reasons: 1) they are sessile and thus indicative of regional PCB distribution, 2) they inhabit the benthic sediments in which large quantities of PCBs have been identified, 3) they are microphagous and selectively process particles in the size range that absorb PCBs (4), and 4) they are significant in local fisheries, both sport and commercial.

MATERIALS AND METHODS

Collection of Specimens

Clams, *Mercenaria mercenaria* (L.), ranging in size between 37 mm and 106 mm

were obtained with an epibenthic sled at depths varying from 3 to 12 meters. The majority of sampling sites were located in Buzzards Bay within a 5.8 nautical mile radius from the entrance to New Bedford Harbor (Figure 1). For comparison, additional specimens were collected from the Westport River, 1.0 nautical miles from its mouth and 14.0 nautical miles from New Bedford Harbor. These organisms served as low level control samples. The precise locations of sampling sites within the study area were determined largely by the distribution of the organisms. The Slocum River estuary was also sampled. Because *M. mercenaria* was not available, we collected *Crassostrea virginica* (Gmelin) as the representative bivalve for this area.

All sampling was conducted during the week of March 11, 1978. Thus, the reported effects of water temperature upon PCB concentrations (5) were obviated. Bottom characteristics of collection sites were variable, ranging from soft mud to unsorted sand densely infiltrated with shell debris.

Analytical Methods

PCBs were quantitatively determined in pooled tissue homogenates. All chromatographic reagents, glassware and equipment contacting the samples were copiously rinsed with redistilled solvents (Reagent Grade, Fisher Scientific Co.) in the following sequence: methanol, acetone, toluene, hexane.

The shucked clams including mantle cavity water were homogenized (Polytron R Kinematica GmbH), lyophilized and extracted three times with hexane (1 x 50 ml, 2 x 25 ml). The extracts were filtered through a column of powdered sodium sulfate (Na_2SO_4) to remove residual water and particulates, then concentrated to 1 ml for column chromatographic clean-up utilizing 10 gm of alumina (200 mesh deactivated 5% with water) and 8 gm of silica gel (60-200 mesh deactivated 5% with water). The columns were first eluted with 15 ml of hexane. The PCBs were then collected in a 50 ml hexane-toluene (80/20) elution and quantitatively concentrated for

analysis on a 7620A Hewlett Packard gas liquid chromatograph utilizing 1.5% OV-17/1.95% QF-1 on Chromosorb W AW 100/200 mesh in a glass (6 ft. x 2 mm i.d.) column and equipped with a Ni⁶³ electron capture detector. Operating conditions for the duration of the chromatographic analysis included: injection port temperature 225°, oven temperature isothermal at 190°; detector temperature 300°, pulse interval 50 msec, carrier gas (95% argon, 5% methane) with a column flow of 20 ml/min and detector purge of 40 ml/min, chart speed 0.5 in/min. Extraction efficiency from spiked samples was 80-90% or better as determined in one of our laboratories.

RESULTS

PCBs reported as Aroclor 1254 were detected in all samples with concentrations ranging from a high of 4.188 ppm (ug/g) dry weight in samples collected adjacent to the harbor, to a low of 0.232 ppm (ug/g) in samples collected approximately three nautical miles from the harbor (Table I). Samples from Westport Harbor, Massachusetts (Site 13) containing 0.008 ppm PCB were considered indicative of background concentrations.

Examination of the data suggests a gradient of decreasing concentration from point source contamination similar in pattern to that reported from the upper Hudson River (6). The lower concentrations found in protected coves and estuaries indicates minimal PCB input from urban runoff.

The Commonwealth of Massachusetts has been prohibiting commercial fishing north of a line drawn from Ricketson's Point, Dartmouth (41°34'38"N; 70°56'19"W) to Black Rock, Fairhaven (41°34'41"N; 70°51'45"W). Sampling sites south of this closed fishing area, however, showed PCB concentrations comparable to those within the restricted area. High PCB concentrations at Sites 6 and 8 may be due to transport paralleling the mass flow of water in Buzzards Bay (7). The

elevated PCB concentration at Site 11 may be due to tidal flushing along the major shipping channel away from the harbor.

We have taken a few samples and analyzed them in more detail in one of our laboratories (W.H.O.I.). These analyses show that the PCBs are composed of a mixture of components similar to 1242 or 1016 and 1254. In addition, we have analyzed a sample of scallops, *Aequipecten irradians* (Lamarck) from Cleveland ledge light (Figure 1) supplied by the Falmouth, Massachusetts shellfish warden. The data from these analyses are presented in Table II.

DISCUSSION

In compliance with the Toxic Substance Control Act, the manufacturing facilities abutting New Bedford Harbor have severely curtailed the discharge of PCBs into harbor waters. All PCB use was, in fact, suspended by September, 1978 (8).

However, the discharge of large amounts of PCBs over the last 38 years (8), coupled with the affinity of PCBs for sediments (9) has resulted in severely contaminated sediments in this area. The literature reveals little data for PCBs in sediments from this area. Harvey *et al.* (10) reported 8.4×10^{-6} g PCB/g dry weight in outer New Bedford Harbor sediments sampled in 1973. Gilbert *et al.* (11) reported values of 0.175 to 0.543×10^{-6} g/g dry weight for concentrations of PCBs in surface sediments from eight stations in Buzzards Bay outside of New Bedford Harbor.

Risebrough *et al.* (12) have analyzed mussels (*Mytilus edulis* L.) from inner New Bedford Harbor and have reported a phenomenally high concentration of 110×10^{-6} g PCB/g dry weight. They also analyzed water from the area and report concentrations of up to 580×10^{-9} g PCB/liter dissolved and particulates combined.

Unpublished data for PCB analyses of shellfish, bottom fish, and sediments

In the New Bedford Harbor area exist in the files of the Commonwealth of Massachusetts, Department of Environmental Quality Engineering. These samples taken and analyzed in 1976 and 1977 show PCB concentration values for sediments ranging between 0.5 and 620×10^{-6} g/g dry weight; up to 11.7×10^{-6} g/g wet weight in lobster (*Homarus americanus* Milne-Edwards) edible tissue; and up to 20.0×10^{-6} g/g wet weight in black back flounder (*Pseudopleuronectes americanus*, Walbaum) edible tissue. These data led to the closure of the New Bedford Harbor area as previously noted.

Summerhayes *et al.* (7) and Stoffers *et al.* (13) have investigated trace metal contamination in New Bedford Harbor sediments. They found very high levels in the inner harbor (up to 1% Cu in surface sediments) and concluded that the harbor area was slowly leaking trace metal contaminated sediments to nearby Buzzards Bay. Processes active in movement of trace metal contaminated sediments are quite likely to be active in the movement of PCB contaminated sediment particles in the same area. In fact, it is likely that trace metals and PCBs are associated with many of the same particles.

Thus, even though the PCB discharges by industry have been curtailed, the harbor sediments contain high concentrations of PCBs and can act as a source of PCB contamination of the harbor for some time to come. Young *et al.* (14) have clearly demonstrated that PCB contaminated sediments can be a source of PCB contamination for shellfish. Rhoads and co-workers (15) have shown that tidal influences in Buzzards Bay result in resuspension of surface sediments in some areas with the resulting probability of transport to other areas of the bay. Disturbance of the sediments in New Bedford Harbor by natural events such as tidal movement or storms or man-induced activities such as dredging will probably result in contamination of other Buzzards Bay areas.

This may be the reason for the PCBs being detected in the bay sediments

(11) or our own findings of PCBs in the scallops at Cleveland ledge light. However, PCBs are so widespread and ubiquitous in coastal regions near industrialized areas that we cannot be certain at present of the origin of the low concentrations of PCBs at Cleveland ledge light and Buzzards Bay surface sediments.

The data on PCBs in New Bedford Harbor are sufficient to identify this area as one of high PCB concentration in both sediments and biota. However, the exact magnitude of the problem has not yet been investigated. The critical questions of the size of the reservoir of PCBs in the sediments of the harbor and the extent to which they are a source for contamination of other areas of Buzzards Bay remain and we are pursuing answers to these questions.

The few higher resolution measurements available to us at this time indicate that there is a substantial concentration of the di-, tri-, and tetrachlorobiphenyls in the area in comparison to the amounts of penta- and hexachlorobiphenyls usually found in environmental samples. This indicates a proximity of the samples analyzed to source of input via effluents. The di- and trichlorobiphenyls are more reactive than the penta- and hexachlorobiphenyls and as distance and time between input and measurement increases, there is a greater probability that the less chlorinated biphenyls will undergo reaction (2). The electrical component manufacturers in New Bedford used primarily 1242 and 1016 PCB mixtures. Thus, the input of the less chlorinated analogs is expected. The New Bedford Harbor and Buzzards Bay ecosystems provide a system to study the biogeochemistry of the various PCB isomers and we are currently pursuing this investigation.

Our data on the PCBs in oysters from the Slocum River estuary (Table I) may suggest a second problem with PCBs in the greater New Bedford area. The PCB concentrations in *C. virginica* from the Slocum River estuary are in excess of those in *M. mercenaria* collected off the river mouth. It is possible that lateral

transport of contaminated sediments from the New Bedford Harbor area to a point upstream in the adjacent Slocum River would exceed transport to a point off the mouth of the river. We think this is unlikely but cannot be more certain because of lack of knowledge about sediment transport in the area. A second possibility, and one we currently think is more likely, is release of PCBs from a landfill site to the aquifer feeding the Slocum River. It has been established that there are over 200,000 kgs of PCBs buried in the New Bedford municipal landfill located on the aquifer feeding the Slocum River valley. A few preliminary measurements have shown that some PCBs are present in waters draining from the landfill (16). Extensive contamination of ground waters was not found, based on a few measurements. However, time series measurements and mass flow calculations have not been made (16). This problem merits more extensive study as the aquifer represents the primary source of drinking water for the Town of Dartmouth, Massachusetts.

Recent measurements of PCBs in the common blue mussel, *Mytilus edulis*, and in oysters, *Crassostrea virginica*, collected around the coast of the United States have shown the northeastern U. S. coastal area as more contaminated with PCBs on a regional basis than most other areas of the coast (17). The data and discussions we have presented here suggest that the New Bedford Harbor area should be considered along with the Hudson River and Chesapeake Bay as one of the sources of these regionally elevated concentrations.

ACKNOWLEDGEMENTS

We thank the officials and scientists of the Commonwealth of Massachusetts, Office for Environmental Affairs, and its various departments for making available unpublished file data and discussions. A.C.D. and J.W.F. acknowledge support by the U. S. Environmental Protection Agency, Grant R 8042-15, the "Mussel Watch" Program.

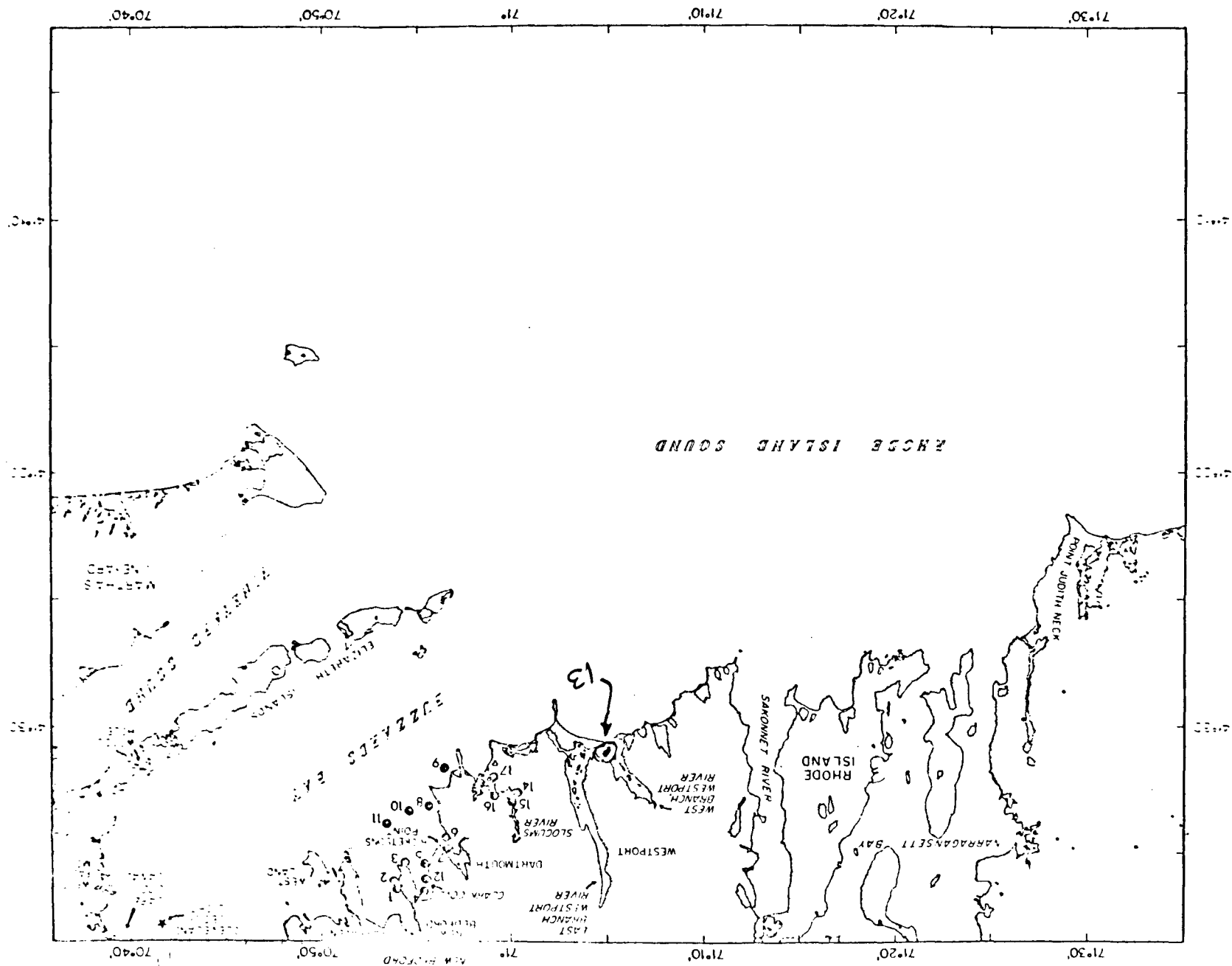
TABLE I

Sampling Site	Organism	Avg. ppm Dry Wt. (ug/g)	Avg. ppm Calculated Wet Wt. (ug/g) PPM	Avg. ppm Dry Wt. Corrected for 80% Extraction Efficiency (ug/g)
1	<i>Mercenaria mercenaria</i> <i>quahauc</i>	4.188	0.524	✓ 5.235
2	" "	1.363	0.170	1.704
3	" "	1.751	0.218	2.189
4	" "	0.443	0.055	0.553
5	" "	1.536	0.192	1.920
6	" "	1.418	0.177	1.772
7	" "	0.290	0.036	0.362
8	" "	0.625	0.078	0.781
9	" "	0.537	0.067	0.671
10	" "	0.232	0.029	0.290
11	" "	1.042	0.130	1.302
12	" "	0.879	0.110	1.099
13	" "	0.008	0.001	0.010
14	<i>Crassostrea virginica</i> <i>oyster</i>	0.560	0.070	0.700
15	" "	2.566	0.321	3.208
16	" "	2.276	0.284	2.845
17	" "	1.472	0.184	1.840

TABLE II

Mixture of 1242 and 1254 PCBs in Selected Samples
from New Bedford Harbor and Buzzards Bay, Massachusetts.

Site	Organism	10 ⁻⁶ g/g Dry Weight	
		1242	1254
3	<i>Mercenaria mercenaria</i>	1.59	1.46
10	" "	0.22	0.20
Cleveland Ledge Light	<i>Aequipecten irradians</i>	0.093	0.185



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Ref # 64

Print

See Ref #141

MEMORANDUM

TO: ~~Hans~~ Bonne
FROM: Russell Isaac RAI
DATE: June 4, 1980
SUBJECT: PCB Samples in New Bedford Discharges

Attached is a copy of results for PCB sampling. Cornell-Dublier is well within the limitation noted in the permit. Aerovox no longer discharges directly to New Bedford Harbor. The wastewater treatment facility also contained a small amount of PCB.

Some shellfish (quahoags) from Falmouth contained much less than the maximum 5mg/kg allowed by FDA.

RI/rg
Enclosure

cc: J. Gould, DWPC, North Pembroke
W. Schwarz, DEQE, Amherst
A. Comproni, DPH, Boston

RECEIVED
JUN 8 1980
MASS DIVISION OF
WATER POLLUTION CONTROL

see Ref #141

The Commonwealth of Massachusetts
Department of Environmental Quality Engineering
Special Analysis

NEW BEDFORD

Collection J. Ackerman

- A Cornell - Dublier, No. 6, Press Room
 B " " , Building, G
 C " " , No. 8
 D " " , No. 9
 E " " , Boiler Room
 F Waster Water Treatment Plant, Chlorine Contact Chamber

	A	B	C	D	E	F
<u> </u>	000472	000473	000474	000475	000476	000477
<u> </u>	3/27/80					
<u> </u>	4/1/80					
ug/L PCB AROCOR #1254	0.0	0.0	0.0	0.0	0.0	0.0
ug/L PCB AROCOR #1016	0.1	0.1	0.0	(0.4)	0.0	0.1

1. ug/L = ppb 2. Samples prepared and extracted at L.E.S. - DEQE
 Samples chromatographed at Lab. Lab.

65

POLYCHLORINATED BIPHENYL (PCB) ANALYSES
OF MARINE ORGANISMS IN
THE NEW BEDFORD AREA,
1976-1980

By

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and

Russell Ceurvels
Chief of Laboratory

January, 1981

Commonwealth of Massachusetts
Division of Marine Fisheries
100 Cambridge Street
Boston, MA 02202

PUBLICATION: #12265 - 36 - 100 - 1 - 81 - CR

APPROVED BY: John Manton, Acting State Purchasing Agent

INTRODUCTION

Polychlorinated biphenyls (PCB's) are highly stable compounds which have been found to be toxic to man and other animals (Weimer et al. 1976). In recent years, their presence in the environment has elicited the concern of several government regulatory and health agencies. PCB's are known to have been utilized by three companies in Massachusetts. The General Electric Corporation, located in Pittsfield, has discharged PCB's into the Housatonic River. Aerovox Corporation and Cornell-Dubilier Corporation, both located in New Bedford, discharged PCB's into the Acushnet River from 1947-1976 and 1942-1976, respectively (E. Wong pers. comm.)¹.

In September, 1976, the Massachusetts Division of Marine Fisheries (DMF) began to analyze finfish, shellfish and crustaceans in New Bedford area waters for PCB content. Sampling was not part of a pre-designed program but was activated as a response to requests from other government agencies for information on PCB levels in edible fish from the area.

On March 8, 1977, the Massachusetts Department of Public Health (DPH) issued a warning that bottom feeding finfish from a portion of Buzzards Bay adjacent to the Acushnet River (Figure 1), should not be consumed as they contain PCB's in excess of the 5 ppm Federal Action Level (FAL). On June 2, 1977, a second warning was issued relative to consuming lobsters. Analysis of additional samples taken from 1977-1979 resulted in a DPH closure of this area on September 25, 1979 (Figure 2). The closed area was divided into three sections. Area 1 was closed to the taking of all finfish, shellfish, and lobsters; Area 2 to the taking of bottom feeding finfish (eels, scup, flounder

¹Edward Wong, Malacologist, U.S. Environmental Protection Agency, Lexington, MA 02173.

WATER RESOURCES DIVISION, MASSACHUSETTS DEPARTMENT OF PUBLIC HEALTH
Map of the State of Massachusetts showing the location of the areas of concern for recreational fishermen.

Figure 1.

MASSACHUSETTS DEPARTMENT OF PUBLIC HEALTH

Water Quality	77.8	76.9	76	76.1	75.1	74
Water Quality	77.8	76.9	76	76.1	75.1	74
Water Quality	77.8	76.9	76	76.1	75.1	74

NEW BEDFORD

FAIRHAVEN

WASKET CREEK BAY

AREA I

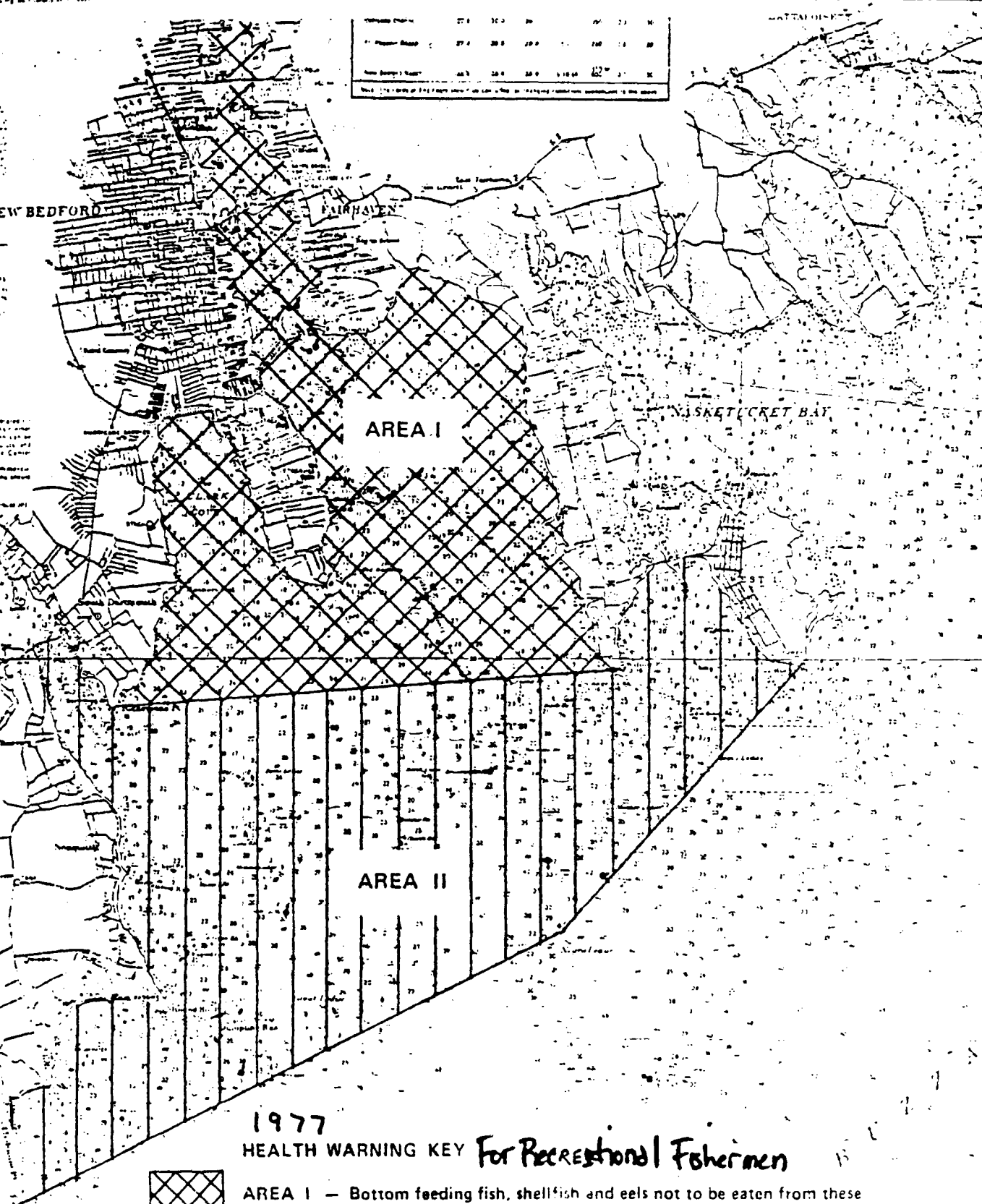
AREA II

1977

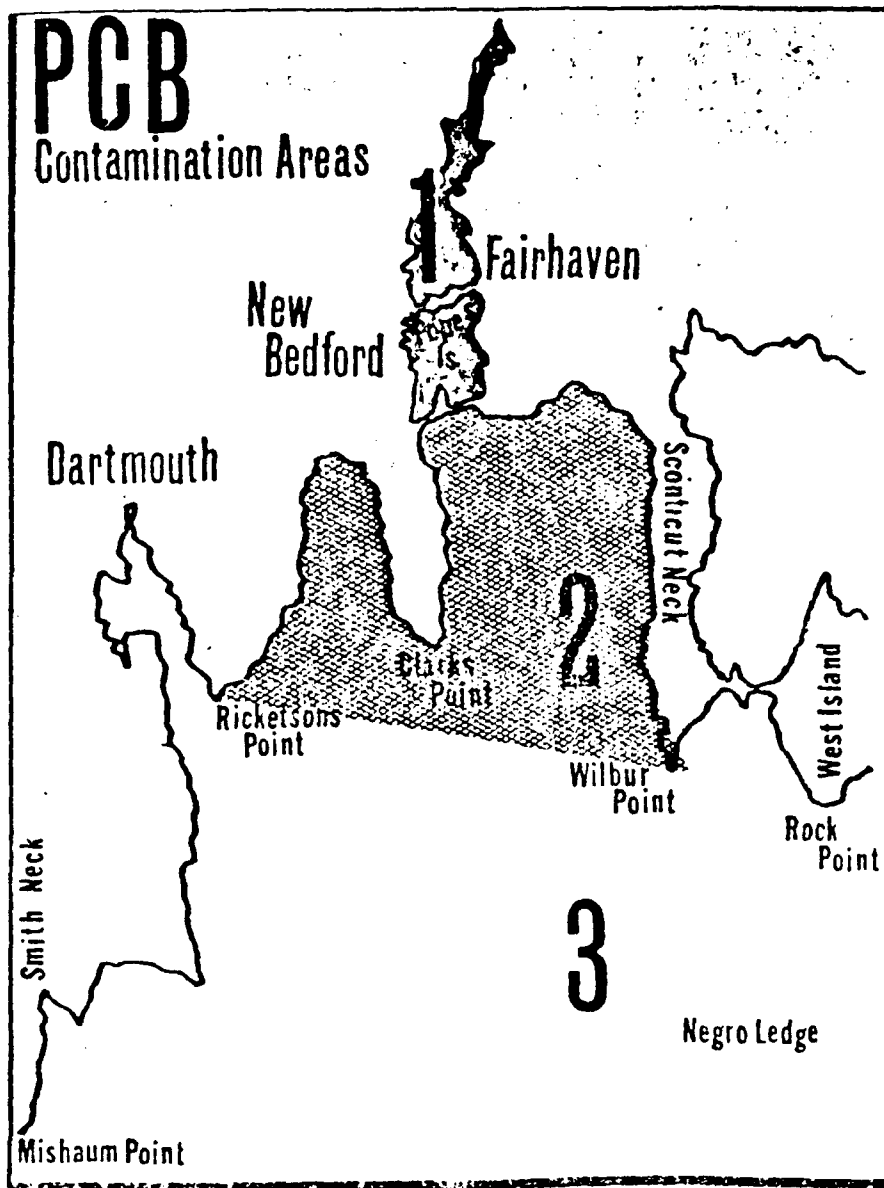
HEALTH WARNING KEY For Recreational Fishermen

AREA I — Bottom feeding fish, shellfish and eels not to be eaten from these waters because of PCB contamination.

AREA II — Bottom feeding fish not to be eaten from these waters because of PCB contamination.



3/7/82



Areas subject to PCB closures include (1) waters closed to all fishing activities, (2) waters closed to lobstering and fishing for bottom feeding finfish, and (3) waters closed to lobstering only.

New Bedford Standard Times 9/26/79.

Figure 2.

1979 Closure

and tautog) and lobsters; Area 3 to the taking of lobsters. Many people felt that the DPH may have over-reacted to the PCB contamination problem. Closure lines were apparently chosen not because they necessarily delineated spatial contamination but because they were readily identifiable and connected convenient points on land. Laboratory analyses indicated that of all the species sampled, only eels consistently contained PCB concentrations exceeding 5 ppm.

DMF continued to analyze for PCB's during 1980 because of this agency's concern with the contamination of marine resources and the impact of the closure on local fisheries. The Division found it necessary to compile, review, and analyze the results of work completed to date. Our objectives entailed: 1) ascertaining the representativeness of the sampling results for the species populations within the closed area; 2) determining whether the closure lines represented contaminated areas; and 3) examining the data for spatio-temporal trends in contaminated levels of biota.

MATERIALS AND METHODS

Samples were collected over a four-year period (1976-1980) utilizing standard collecting gear applicable to the species sought, (e.g. otter trawl, lobster pot, eel pot, hook and line, and clam rake). During 1976 and 1977 when a sample was taken, we recorded location, date, and species identification information. On subsequent samplings, we also obtained data on the length, weight, and sex of the organism sampled; water temperature, and salinity. Each sample was grossly examined externally for abnormalities and disease. Finfish were also examined internally.

Three laboratories were involved in analyzing the samples for PCB concentrations. Only edible portions of each sample were utilized for gas chromato-

graph analysis. The DMF's Cat Cove Laboratory employed a Tracor MT 220 gas chromatograph, the Lawrence Experimental Station of the Department of Environmental Quality Engineering employed a Perkin Elmer gas chromatograph, and the United States Food and Drug Administration's Boston Laboratory utilized a Tracor 560 gas chromatograph. Analyses were performed following the FDA procedure found in Pesticide Analytical Manual, Volume 1, Section 212.13a. This procedure has a sensitivity of <0.1 ppm.

The three laboratories also split and analyzed six samples as a means of comparing instruments and techniques. The mean of all the samples was 5.0 with a standard error of 0.7.

STUDY AREA

Study area boundaries and site locations are shown in Figure 3. Areas 1, 2, and 3 are described in the DPH closure notice (Appendix 1). For the purposes of this report, the region outside of the closure has been designated Area 4. Sites A and M are adjacent to the Aerovox and Cornell-Dubilier discharges, respectively. Site V is the New Bedford sewage outfall. The presence of PCB's in the sewage effluent and sediment adjacent to the outfall pipe indicate that this is also a source of contamination (Camp Dresser and McKee, Inc., 1979). The spoil area depicted in Figure 3 was utilized in 1953 for the deposit of spoil taken from New Bedford inner harbor and in 1962 and 1966 for spoil dredged from the outer harbor.

RESULTS AND DISCUSSION

PCB levels by species are listed in Tables 1 and 2. In general, organisms

Table 1. Concentrations in ppm, of PCB's in the New Bedford area fin-fish and shellfish species (except lobster) at all sites.

Species	Area	Site	Date	PCB (ppm)
Winter flounder, <u>Pseudopleuronectes americanus</u>	1	G ✓	9/23/76	6.0
	2	LL ✓	9/23/76	5.6
	● 3	EE ✓	9/23/76	2.6 (3.9)
	2	BB ✓	9/23/76	11.0
	● 4	FF ✓	9/23/76	11.0 (20)
	3	GG ✓	9/23/76	5.6
	● 1	I ✓	9/23/76	13.0 (22)
	2	LL ✓	7/10/79	7.5 ^a
	1	MM	8/23/79	8.1 ^b
	3	BBB	10/16/79	0.2
	3	CCC	10/16/79	1.6
	3	CCC	10/16/79	0.9
	3	DDD	10/16/79	0.8
	3	EEE	10/16/79	0.6
	3	FFF ✓	10/16/79	0.5
	3	FFF ✓	10/16/79	0.5
	3	GGG ✓	10/16/79	0.8
	3	HHH ✓	10/16/79	1.0
	3	HHH ✓	10/16/79	0.2
	2	Q ✓	6/10/80	3.8
Striped bass, <u>Morone saxatilis</u>	2	KK ✓	4/28/77	0.4
	2	KK ✓	5/ 5/77	0.5
	2	KK ✓	5/ 6/77	3.0
	2	S ✓	5/20/77	2.7
Bluefish, <u>Pomatomus saltatrix</u>	2	KK	5/21/77	1.0
	2	KK	5/21/77	1.6
	2	S ✓	8/30/79	16.5
	2	S	8/30/79	1.4
American eel, <u>Anguilla rostrata</u>	1	H ✓	7/10/79	24.0 ^c
	2	Q ✓	7/10/79	38.0
	1	A	7/11/79	460.0
	1	A	7/11/79	730.0
	1	A	7/11/79	670.0
	1	A	7/11/79	430.0
	1	A	7/11/79	430.0

a. Composite sample of 3 flounder.

b. Composite sample of 5 flounder.

c. Composite sample of 3 eels.

Table 1. Continued

Species	Area	Site	Date	PCB (ppm)
American eel, <u>Anguilla rostrata</u>	1	A ✓	7/11/79	570.0
	1	H ✓	8/16/79	24.0 ^d
	1	H ✓	8/16/79	19.0 ^e
	1	A ✓	8/17/79	24.0
	1	A ✓	8/22/79	33.0
	1	A ✓	8/22/79	11.0
	1	A ✓	8/22/79	18.0
	2	P ✓	7/26/79	13.8
	2	P ✓	7/26/79	12.2
	1	A,B,&C	9/23/76	92.0 ^f
Scup, <u>Stenotomus chrysops</u>	2	R ✓	9/23/76	6.1
	2	II ✓	9/23/76	11.4
	1	MM ✓	8/23/79	2.3 ^g
	3	III ✓	10/ 4/79	1.3
	3	AAA ✓	6/ 4/80	0.0 ^h
	3	DDD ✓	6/ 4/80	0.0 ⁱ
Summer flounder, <u>Paralichthys dentatus</u>	● 2	U ✓	9/23/76	7.9
	● 1	I ✓	9/23/76	10.0
	● 2	L ✓	9/23/76	7.1
	2	Y ✓	7/11/79	0.2
	1	MM ✓	8/23/79	2.1
	3	EEE ✓	5/29/80	0.3
	3	DDD ✓	6/ 4/80	4.0
Windowpane, <u>Scophthalmus aquosus</u>	1	MM ✓	8/23/79	5.5 ^j
	1	MM ✓	8/23/79	14.3 ^k
	1	MM ✓	8/23/79	8.8 ^l
	3	EEE ✓	10/16/79	3.1
	3	FFF ✓	10/16/79	3.1
Tautog, <u>Tautoga onitis</u>	2	II ✓	9/23/76	1.2
	2	LL ✓	7/10/79	1.3 ^m
	2	S ✓	7/11/79	1.3

d. Composite sample of 4 eels.

e. Composite sample of 4 eels.

f. Three sites sampled.

g. Composite sample of 31 scup.

h. Composite sample of 6 scup.

i. Composite sample of 7 scup.

j. Composite sample of 8 windowpane.

k. Composite sample of 9 windowpane.

l. Composite sample of 8 windowpane

m. Composite sample of 6 tautog.

Table 1. Continued

Species	Area	Site	Date	PCB (ppm)
Tautog, <u>Tautoga onitis</u>	3	AAA	10/16/79	0.3
	3	AAA	10/16/79	0.8
	3	AAA	10/16/79	0.1
	2	II	6/10/80	1.1
	2	LL	6/10/80	0.2
	3	GGG	6/10/80	0.9
	3	GGG	6/10/80	1.1
	3	GGG	6/10/80	0.7
	3	GGG	6/10/80	0.7
	2	Y	6/10/80	4.6
	2	Z	6/10/80	0.8
	2	Z	6/10/80	0.1
Silver hake, <u>Merluccius bilinearis</u>	2	U	9/23/76	0.7
Red hake, <u>Urophycis chuss</u>	3	EEE	10/16/79	0.1
Fourspot flounder, <u>Paralichthys oblongus</u>	3	AAA	6/10/80	0.8
Cunner, <u>Tautogolabrus adspersus</u>	● 2	U	9/23/76	20.0 (57)
Black sea bass, <u>Centropristis striata</u>	3	III	10/ 4/79	0.4
Butterfish, <u>Peprilus triacanthus</u>	● 4	QQ	9/23/76	0.3 (0.7)
X Blue crab, <u>Callinectes sapidus</u>	2 X	M	8/14/79	4.2 ⁿ
	1 X	G	8/16/79	4.2 ^o
	1*	A,B,&C	9/23/76	1.0 ^p
	1 X	G	9/23/76	5.6
X Soft-shelled clam, <u>Mya arenaria</u>	✓1	D	9/23/76	53.0
	✓1	E	9/23/76	21.0
	✓1	F	9/23/76	22.0
	✓1	F	8/16/79	14.6
X Oyster, <u>Crassostrea virginica</u>	✓1	NN	8/16/79	15.8
X Quahog, <u>Mercenaria mercenaria</u>	✓2	Q	9/23/76	1.3
	✓2	DD	9/23/76	0.2
	✓2	CC	9/23/76	0.2
	✓3	AA	9/23/76	0.5
	✓2	Z	9/23/76	0.4

n. Composite sample of 5 blue crabs.

o. Composite sample of 4 blue crabs.

p. Three sites sampled.

Table 1. Continued

Species	Area	Site	Date	PCB (ppm)
Quahog, <u>Mercenaria mercenaria</u>	~2	Y	9/23/76	0.7
	~2	V	9/23/76	1.8
	~3	W	9/23/76	0.4
	~3	X	9/23/76	0.4
	~2	KK	9/23/76	0.7
	~2	JJ	9/23/76	3.3
	~4	OO	9/23/76	0.1
	~4	PP	9/23/76	0.1
	~3	HH	9/23/76	0.3
	~2	Z	8/ 9/79	1.1
	~3	CC	8/ 9/79	0.6
	~1	NN	8/16/79	1.6
	~2	II	8/16/79	0.3
	~2	R	8/16/79	0.6
	~2	JJ	8/16/79	0.8

Table 2. Concentrations of PCB's in New Bedford area lobsters, Homarus americanus.

Area	Site	Date	PCB (ppm)
2	T	3/16/77	7.9 ✓
2	T	3/14/77	1.2 ✓
2	T	5/ 6/77	9.3 ✓
2	T	7/ 6/78	2.7
2	T	7/ 6/78	9.0
2	T	7/ 6/78	1.7
2	T	7/ 6/78	2.5
2	T	7/ 6/78	1.4
2	T	7/ 6/78	1.0
2	T	7/ 6/78	2.7
2	T	7/ 6/78	1.7
2	T	7/ 6/78	1.4
2	T	7/ 6/78	1.4
2	T	7/ 6/78	1.7
2	T	4/20/79	2.0
2	T	4/20/79	20.6
2	T	4/20/79	8.7
2	T	4/20/79	6.1
2	T	8/ 8/79	68.2 ✓
2	S	3/14/77	2.2 ✓
2	S	5/ 6/77	6.3 ✓
2	S	7/ 6/78	3.5 ✓
2	S	7/ 6/78	5.4 ✓
2	S	7/ 6/78	2.2 ✓
2	S	7/ 6/78	3.7 ✓
2	S	4/20/79	17.0 ✓
2	S	8/ 8/79	15.4 ✓
2	R	3/18/77	3.1 ✓
2	R	5/ 6/77	11.7 ✓
2	R	5/ 6/77	8.2 ✓
2	R	7/ 6/78	4.7 ✓
2	P	3/16/77	1.0 ✓
2	Q	4/20/79	15.6 ✓
2	Q	4/20/79	7.6
2	Q	4/20/79	1.1
2	Q	4/20/79	0.8
2	Q	8/16/79	31.1 ✓
2	Q	8/16/79	30.3 ✓
2	Q	8/16/79	23.8 ✓
2	Q	8/16/79	26.6 ✓
2	M	8/16/79	63.4 x
2	M	8/16/79	27.4 x
3	HH	3/17/77	2.1 ✓
3	HH	5/ 6/77	5.8 ✓
3	HH	8/14/79	11.6 ✓
3	HH	8/14/79	12.4 ✓
3	RR	10/ 5/79	10.6 ✓

Table 2. Continued

Area	Site	Date	PCB (ppm)
3	SS	10/ 5/79)	2.9 X
3	SS	6/ 6/80	4.4 X
3	SS	6/ 4/80	2.3 X
3	SS	6/ 4/80	7.4 X
3	TT	10/ 5/79	9.4 X
3	UU	10/11/79	2.3 X
3	UU	7/28/80	3.1 X
3	UU	7/28/80	3.3 X
3	UU	7/28/80	2.1 X
3	VV	10/11/79	10.4 X
3	VV	7/25/80	2.0 X
3	VV	7/25/80	1.4 X
3	VV	7/25/80	4.1 X
3	WW	10/11/79	35.5 X
3	WW	6/ 4/80	3.9 X
3	WW	6/ 4/80	6.0 X
3	YY	10/16/79	4.7 X
3	YY	6/23/80	8.2 X
3	YY	6/23/80	2.9 X
3	ZZ	10/19/79	3.8 *
3	ZZ	10/19/79	3.8 *
3	ZZ	10/19/79	3.8 *
3	ZZ	6/ 4/80	3.4 X
3	ZZ	7/25/80	4.7 X
3	ZZ	7/25/80	2.0 X
3	ZZ	7/25/80	2.6 X
3	MMM	10/29/79	5.0 X
3	MMM	6/30/80	2.7 X
3	MMM	6/27/80	4.7 X
3	MMM	6/27/80	6.1 X
3	LLL	10/29/79	7.9 X
3	JJJ	10/29/79	10.6 * X
3	JJJ	10/29/79	10.6 *
3	JJJ	10/29/79	10.6 *
3	JJJ	6/25/80	7.6 X
3	JJJ	6/25/80	5.5 X
3	JJJ	6/25/80	4.3 X
3	KKK	10/26/79	7.1 *
3	KKK	10/26/79	7.1 *
3	KKK	10/26/79	7.1 *
3	KKK	7/28/80	3.8 X
3	KKK	7/28/80	11.0 X
3	KKK	7/30/80	2.4 X
3	KKK	6/23/80	5.5 X
4	000	12/14/79	3.4 * X

* Average of all lobsters taken at site.

Table 2. Continued

Area	Site	Date	PCB (ppm)
4	OOO	12/14/79	3.4 **
4	OOO	12/14/79	3.4 **
4	NNN	12/19/79	5.2 **
4	NNN	12/14/79	5.2 **
4	NNN	12/14/79	5.2 **
4	QQQ	12/14/79	2.0 **
4	QQQ	1/18/80	2.0 **
4	PPP	12/14/79	4.8 **
4	PPP	1/22/80	4.8 **
4	PPP	1/22/80	4.8 **
4	PPP	1/22/80	4.8 **
4	RRR	1/18/80	7.2 **
4	RRR	1/18/80	7.2 **
4	SSS	12/19/79	2.2 **
4	SSS	1/18/80	2.2 **
4	SSS	1/18/80	2.2 **
4	SSS	1/18/80	2.2 **
4	SSS	1/18/80	2.2 **

sampled in Area 1 were found to contain the highest PCB levels. Those obtained from Areas 3 and 4 contained lesser concentrations of the contaminant. Farrington (unpublished report) reported that PCB levels in the sediment were also highest in Area 1 (Appendix 2). The Hurricane Dike appears to be acting as a sediment trap containing much of the PCB-laden sediment within the inner harbor. Summerhayes et al. (1977) demonstrated that sediments outside the inner harbor are transported in a net northerly direction. Analyses reported to date by Farrington (unpublished report) and Camp Dresser and McKee, Inc. (1979) indicate that most of the contaminated sediment is found north of the Area 2 closure line.

We have observed no overt effects of PCB uptake on marine organisms in the area, even though some contained PCB levels exceeding 100 times the FAL. Gross inspection revealed no abnormalities or indications of disease symptoms in any of the animals sampled and/or observed. Seasonal development of the reproductive organs of the finfish examined appeared to be normal.

Finfish

2 The DPH has implied that all bottom-feeding finfish in Area 2 contain PCB levels which exceed the FAL (Appendix 1). The data, however, do not support this contention. PCB concentrations in tautog, fourspot flounder, red hake and sea bass never exceeded 5 ppm. Elevated PCB levels are found in fish that are bottom-dwelling and year-round residents as well as bottom-feeding, i.e. eels, winter flounder and windowpane flounder. Weimer et al. (1976) have stated that fish can take up PCB's directly through the gills and integument. Long-term contact with the sediment most likely allows PCB's to be absorbed in this manner.

Eels

Eels have contained the highest PCB levels of all species tested. Three factors contribute to this phenomenon: 1) eels spend most of their adult life (5-20 yrs) in the same water body (Fahay 1978); 2) they are chiefly nocturnal and often lie buried in the mud during the daytime (Bigelow and Schroeder 1953). Their activity is reduced as water temperature declines and they spend most of the winter burrowed in the mud in direct contact with the PCB-laden sediment; 3) their body tissue is comprised of 26% fat (Tesch 1977). This is approximately 10 times higher than the average fat content of other species tested. Fat provides the principal storage site for PCB compounds, which are lipophilic (Nimmo et al. 1971b).

Winter flounder

Over the four-year testing period, most winter flounder collected from Areas 1 and 2 have contained PCB concentrations exceeding the FAL. The PCB levels, however, are substantially lower than those found in eels. Of note, there is an apparent reduction in the average contamination levels since 1976 (Table 3). A factor possibly contributing to the elevated levels in winter flounder is the animal's habit of lying buried in the substrate except when actively feeding or migrating (Bigelow and Schroeder 1953). In addition, flounder spend their entire first year of life in the estuary. Most adult fish leave the estuary in the spring after spawning and migrate to cooler water, returning to the estuary in autumn. However, Howe et al. (1976) found that approximately 20% of the flounder up to age IV pass the summer in the estuary.

Table 3. Average PCB concentrations, in ppm, for winter flounder by year by area. Number of individuals in parenthesis.

<u>Year</u>	<u>Area 1</u>	<u>Area 2</u>	<u>Area 3</u>
1976	9.5 (2)	8.3 (2)	4.1 (2)
1979	8.1 (1)	7.5 (1)	0.7 (10)
1980	-	1.9 (2)	2.7 (3)

Windowpane flounder

Windowpane flounder spend their entire lives in estuarine-near shore habitat. Therefore, they would be consistently exposed to a PCB contamination source. They do not bury themselves as do winter flounder but are bottom dwellers and do lie in contact with the substrate. Windowpane flounder were sampled only in 1979. PCB concentrations in these species averaged 9.5 ppm in Area 1 and 3.1 ppm in Area 3.

Summer flounder

The summer flounder (fluke) is likewise a bottom dweller. However, differing from the winter flounder, it is an active swimmer and is found inshore only from May-September. In 1976, the average PCB level in the three summer flounder sampled was 8.3 ppm. However, none of the four fish sampled since that time have exceeded the FAL.

Scup

Like the summer flounder, no scup has exceeded the FAL since 1976. This fish rarely comes in contact with the bottom but does feed close to the bottom. It is a seasonal visitor to the area, residing inshore from May-October.

Bluefish

During 1979, one bluefish was found to contain 16.5 ppm of PCB. However, the average level of the other three bluefish analyzed was only 1.3 ppm. The bluefish is a migratory pelagic species, generally traveling in like-size groups (Wilk 1977). Although it is caught in New Bedford outer harbor from May-October, temporal size range of sportfish catches indicate that most fish remain in the area no longer than four to five weeks before moving elsewhere (R. Lawton pers. comm.)². Test results from other locations in the state are all below the FAL.

Other finfish

② Striped bass, silver hake, and butterfish were never found to contain PCB's which exceeded the FAL.

Shellfish

The distribution of shellfish is such that all oysters and soft-shell clams were taken from Area 1 and all quahogs from Area 2. One would suspect that these shellfish dwelling on or in the substrate and feeding at the sediment-water interface would have a high PCB content. This was true of soft-shell clams and oysters (Table 1). However, quahogs contained relatively low amounts of PCB's. Only one sample exceeded 2 ppm concentration (Table 1). This may be attributed to the very low fat content of the quahog (0.9%), as listed in Gibbons (undated), when compared to soft-shell clams (1.9%) and oysters (1.8%) and lower level of PCB contamination in Area 2 sediment.

²R.P. Lawton, Senior Marine Fisheries Biologist, Massachusetts Division of Marine Fisheries, Sandwich, MA 02563

Crustaceans

Blue crabs

Blue crabs are basically bottom dwelling and omnivorous, generally found in the estuary. All blue crabs for this study were collected from Area 1. In 1976, one sample was found to have a PCB content exceeding the FAL. Twelve other samples contained less than 5 ppm PCB. Harvesting of blue crabs is not prohibited.

Lobsters

The lobster is the only species that was harvested commercially in the closed area. Approximately 50 commercial and 100 recreational lobstermen were affected by the closure. The value of the commercial fishery in this area was estimated to exceed \$125,000 in 1977.

The lobster is also a bottom dweller which feeds on a variety of organisms. Being nocturnal, it searches for food at night and rests in a mud burrow or other suitable shelter during the daytime. Lobsters range from near shore to depths of 700 meters (Cobb 1976). Resident and migratory lobster populations have been documented (Krouse 1980), with stocks often mixing in a given area. Possible migration and movement in general of lobsters within the study area have not been investigated. Fishermen believe that lobsters in the area follow a migration circuit each year. They base this premise on the seasonal catch pattern which is characterized by good spring and fall catches interspersed with a poor summer catch. A similar phenomenon was studied in Connecticut by Stewart (1972). He reported that mass molting in the spring resulted in many former sublegals being recruited to the fishery. In early summer many of the lobsters emigrated, however, a remnant summer population was also noted. Good

fall fishing, according to Stewart, was the result of immigration from deeper water in conjunction with a second mass molt.

The task of examining the data for possible trends in PCB levels is confounded by seasonal movements of lobsters in and out of the study area. Furthermore, daily movements may expose each lobster to contact with varying amounts of PCB's. The rate of uptake of PCB's in lobsters has not been investigated. Studies conducted on other crustaceans indicate that PCB uptake may be rapid (Nimmo et al. 1971a; Sanders and Chandler 1972). Nimmo et al. (1974) found that the shrimp (Palaemonetes pugio) concentrated PCB's within a few days of exposure. Following exposure to water containing 0.17 ppb PCB for 7 days, the test shrimp were found to contain in excess of 1200 ppb PCB. However, further testing revealed that up to 90% of the PCB content per individual was depurated within four weeks following the cessation of exposure treatments.

Table 2 lists PCB levels of the 111 lobsters analyzed. During the study period lobsters with PCB concentrations exceeding the FAL were sampled at most sites. The present closure boundaries do not appear to extend beyond the region of contamination. Nevertheless, only 30% of the samples collected from Area 3 in 1980 exceeded the FAL compared to 70% in 1979.

Furthermore, no contaminated lobsters were found in three of the five southernmost sampling locations (Figure 3), i.e., sites UU, ZZ, and EE. Only one contaminated lobster was sampled at sites VV and YY, respectively. Since the aforementioned sites were only sampled in 1979 and 1980, additional data are needed to determine the appropriateness of the spatial delimitation of the closed area.

Because of the importance of the local lobster fishery, data were subjected to greater scrutiny than the previous species discussed. Table 4 lists

Table 4. Average PCB concentrations, in ppm, for lobsters in areas 2, 3, and 4 for each year. Numbers of individuals in parenthesis.

Year	Area 2	Area 3	Area 4
1977	5.6 (9)	3.9 (2)	3.9 (2)
1978		2.9 (16)	2.9 (16)
1979	21.7 (17)	8.8 (20)	3.8 (10)
1980		4.3 (27)	3.9 (10)

Handwritten notes:
 1977 sample area 2
 1978 sample area 3
 1979 sample area 2
 1980 sample area 3
 2

4
average PCB levels for each sampling year by area. The reason for the high average values in 1979 is unknown. Forty-two percent of the total lobster samples were collected that year. It was found that the high readings obtained from the 1979 sampling, greatly influenced pooled data averages when assembled by sex, size, or season. Examining the variables within an individual year is more enlightening.

Seasonal changes are apparent
Average PCB content by area was the only consistent pattern observed. For each year where data exist, the highest average readings were recorded from Area 2 followed by Areas 3 and 4, respectively. It is reasonable to assume that lobsters taken from Area 2 accumulate at least some PCB's from their immediate environment. Limited sediment analyses undertaken by DMF and Camp Dresser and McKee, Inc. (1979) indicate that PCB's are present in Areas 1 and 2. A possible PCB contamination source in Areas 3 and 4 is the "spoil area" (Figure 3). Sediments from this site have not been analyzed.

3
Data found in Table 5 suggest that with an increase in size of lobsters taken from Area 2 during 1978 and 1979, there is an increase in the average PCB level. Non-migratory lobsters who are older and larger animals would have been exposed to PCB's for a longer period of time and might be expected to contain higher PCB levels. However, the large difference between 1978 and 1979, concentrations intimate that some factor in addition to exposure time has an influence on PCB uptake.

were the big 1 lb 2 oz lobsters? analyzed.
Analyses of average PCB levels grouped by sex (Table 5) and season (Table 6) do not reveal any apparent trends. Utilizing Wilcoxon's signed rank test, differences in average PCB content between sexes were found not to be statistically significant. Gaps in the data record when grouped by season preclude the use of statistical analysis.

Table 5. Average PCB concentrations, in ppm, for lobsters by size and sex in areas 2, 3, and 4 for each year. Numbers of individuals in parenthesis.

Year	Carapace Length (mm)	Area 2		Area 3		Area 4	
		Male	Female	Male	Female	Male	Female
1977	< 81	8.8 (4)		5.8 (1)			
	81-85						
	86-90						
	> 90						
1978	< 81		3.1 (6)				
	81-85	1.6 (2)					
	86-90	2.2 (3)	3.6 (3)				
	> 90	3.7 (2)					
1979	< 81	.77 (1)		13.4 (6)	6.0 (9)	5.2 (2)	3.1 (4)
	81-85				8.3 (5)	3.4 (1)	5.2 (1)
	86-90	22.5 (4)	14.8 (3)				3.4 (2)
	> 90	25.8 (9)					
1980	< 81			5.1 (6)	4.0 (7)	3.5 (2)	2.1 (2)
	81-85			2.0 (2)	4.5 (10)	3.5 (2)	4.7 (3)
	86-90			4.7 (2)			
	> 90						

Table 6. Average PCB concentrations, in ppm, for lobsters in areas 2, 3, and 4 during each season for each year. Numbers of individuals in parenthesis.

Season	Year	Area 2	Area 3	Area 4
3/1 - 6/30	1977	5.7 (9)	4.0 (2)	
	1978			
	1979	8.8 (9)	5.0 (15)	
	1980			
7/1 - 9/30	1977			
	1978	2.9 (16)		
	1979	36.2 (8)	12.0 (2)	
	1980		3.6 (12)	
10/1 - 2/29	1977			
	1978			
	1979		9.5 (18)	3.6 (10)
	1980			4.0 (10)

5

CONCLUSION

Review of the data collected to date indicate that sampling results are insufficient to establish definitive PCB trends in the biota of New Bedford Harbor.

RECOMMENDATIONS

1. It is recommended that the DPH, DMF and other interested state agencies coordinate a comprehensive survey of the closed area to: 1) establish definitive levels of PCB's in the biota and sediments; and 2) determine whether these levels are constant or variable.
2. Present DPH restrictions in the closed area should be reevaluated as soon as possible.
3. Major industrial and sewage outfalls in the area should be monitored to assure that additional PCB contaminants are not entering the Harbor.
4. Depuration rates of PCB's in lobsters and other migratory species should be ascertained through appropriate scientific investigations.

Appendix 1.



The Commonwealth

Department of Public Health

Drew Koler

H.

600 Washington Street

Boston 02111

JONATHAN E. FIELDING, M.D., M.P.H.
Commissioner

CONTACT: Pat Mazza 727-2660
2661

FOR RELEASE - Tuesday, March 8, 1972 - AM

Public Health Commissioner Dr. Jonathan Fielding today requested that bottom feeding fish, shellfish and eels not be taken for eating from the Acushnet River area for health reasons. This area extends north of a line between Picketson's Point to Wilbur Point.

Fielding made this request after reviewing the results of a recent state survey that revealed the presence of Polychlorinated Biphenyls (PCB) in that area which is a recreational fishing area -- not commercial.

The survey revealed that fish in the Acushnet River -- an area that has been closed to shellfish taking for many years because of bacterial pollution -- have been affected by PCB contamination.

PCBs have been used in industrial production and were deposited in the river over the past 10 years. They are no longer being deposited. The fish in this area have been found to have PCB levels that exceed the Federal standard for food.

Fielding noted that the specific health effects of PCBs are not totally known to date, but that it could cause serious illness if ingested frequently over an extended period of time. He continued, "This problem really affects the recreational fisherman who fishes in this river area and then goes home and freezes the catch to

eat over a period of time. This sport fisherman and his family ingest a fair amount of PCB over a period of time." "With this in mind," Fielding continued, "We are now issuing a health warning to recreational fishermen not to eat shellfish, bottom feeding fish and eels from this area."

Fielding is also extending a health warning to recreational fishermen not to eat bottom feeding fish from the area just beyond the Acushnet River area-- north of a line running from Wishaum Point to Gong "3" on Hursett Rock to Rocky Point on West Island. Samples taken from this area showed bottom feeding fish to have elevated PCB levels.

Fielding noted, "These affected areas are used for recreational fishing. There is no commercial fishing in either of these areas for which I have issued health warnings. This fact has been further verified by no increased PCB levels found in fish samples at commercial landings and in the marketplace."

The Department of Public Health will continue to monitor the fish at commercial landings and in the markets as a further precaution.

The Department of Environmental Quality Engineering and the Division of Marine Fisheries have done the sampling and laboratory testing on the fish, shellfish and crustaceans in these waters for PCB determinations. According to DEQE Commissioner David Standley, they will continue the monitoring efforts.

State health and environmental officials have met with legislators and community representatives of the affected areas in advance of issuing these health warnings.

260.003: Authority

These regulations are promulgated under authority of G.L. c.111, ss.5 and 6, G.L. c.94, ss.186 and 192, G.L. c.30A, s.2.

260.004: Adulterated Fish

Fish, containing levels of PCBs exceeding the maximum allowable level (or "temporary tolerance") of PCBs established by the Federal Food and Drug Administration for the edible portion of such food sources are adulterated within the meaning of G.L. c.94, s.186, first paragraph under food. Such food sources caught in the contaminated area are presumed to be contaminated.

260.005: Taking and/or Sale of Lobsters and Certain Fish Prohibited

(1) No person shall take and/or sell any fish (except bait fish), lobster or shellfish from the area of New Bedford Harbor (Area I) described below:

The waters north of the Hurricane Dyke in New Bedford Harbor.

(2) No person shall take and/or sell any lobster or bottom-feeding fish (including eels, scup, flounder and tautog) from the area of New Bedford Harbor (Area II) described below:

The waters generally south of area I and north of a line extending from Ricketson's Point in South Dartmouth westerly to Wilbur Point on Sciticut Neck.

(3) No person shall take and/or sell lobsters from the area of New Bedford Harbor (Area III) described below:

The waters generally south of area II and north of a line extending from Misham Point on Smith Neck in the town of Dartmouth north and west to Cong. "3" on Hursett Rock off New Bedford Harbor and continuous north and west to Rocky Point on West Island in the town of Fairhaven.

CLOSURE NOTICE
SEPT 25, 1979

Appendix 2. Compiled by John Farrington, WHOI.

PCB Analysis.
Results of samples taken in New Bedford Harbor and Buzzards Bay analyzed by Massachusetts State and U.S. Federal labs.

Sediment				Aroclor 1254, 10 ⁻⁶ g/g Dry Wt. Laboratory					
Date	Sample	Location	Site	C.C.	L.E.S.	E.P.A.	F.D.A.	W.H.O.I.	S.M.U.
5/10/76	Sediment (Composite Grab)	Acushnet River	ARS-10	—		620			
			NBS-4	—		143			
			NBS-5	—		2			
			NBS-6	—		0.5			
9/23/76	" "	" "	K	85		47			
			MM	88		75			
			J	18		61			
			MM	23		22			
9/23/76		Outer Harbor	K	0.5		78			
			LL	—		4			
			JJ	0.16		0.3			
5/10/78	Cores Avg. 0-8 cm	Acushnet River	1		9.0				
		Inner Harbor	2		3.0				
			3		3.5				
			4		4.6				
			5		5.9				
			6		5.1				
			7		26.0				
			8		17.1				
			9		13.4				
			10		2.4				
			11		4.5				
			12		5.3				
			12A		9.8				
			13		8.6				
			14		2.7				
			15		7.2				
			16		7.0				
			17		7.9				
			19		7.4				
			20		5.2				
		Outer Harbor	22		7.2				
			22A		7.6				
			23		0.4				
6/73	Sediment Grab	Outer Harbor	—					8.4	
6/79	Core 0-4 cm	" "	~ 23					0.2/0.3*	
5/73	Composite Grab	Buzzards Bay	14 Sta.						0.07 to 0.54

* Results indicate 10⁻⁶ g/g dry wt. of Aroclor 1242/1254.

Laboratory Identification:

C.C. — Massachusetts Division of Marine Fisheries, Cat Cove Marine Laboratory.

L.E.S. — Massachusetts Department of Environmental Quality Engineering, Lawrence Experimental Station.

E.P.A. — U.S. Environmental Protection Agency, Florida Lab.

F.D.A. — U.S. Food & Drug Administration, Boston Lab.

W.H.O.I. — Woods Hole Oceanographic Institution.

S.M.U. — Southeastern Massachusetts University.

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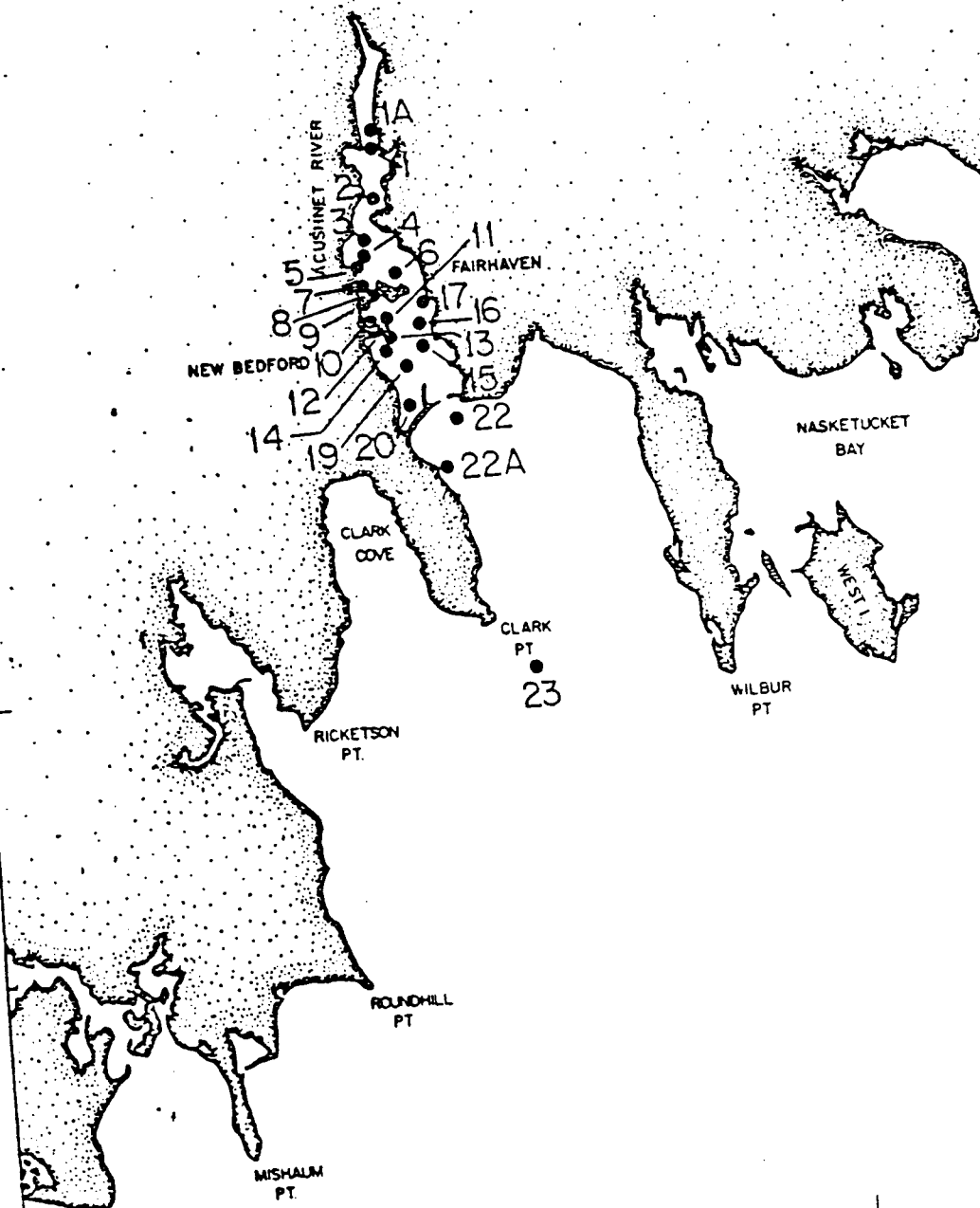
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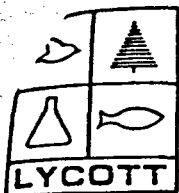
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12 f # 66

7/21/80 Analytical sample
from over flow under cooling
Tower when recycling
system malfunctioned for
approximately 3 hours.



LYCOTT ENVIRONMENTAL
RESEARCH, INCORPORATED
SOUTHBRIDGE, MA. 01550
617-765-0101

Client: Aerovox Industries, Inc.
P.O. Box B-970
740 Bellville Avenue
New Bedford, MA 02741

Date of Collection: 7/21/80

Date Received: 7/23/80

MA003379

Former
NPDES limits

LABORATORY ANALYSIS

Analysis Number	1209	Avg. Daily	↓ Max Daily
Total Chromium	.05	.5	1.
Total Copper	.08	.5	1.
Total Iron	1.75	1.	2.
Total Lead	.28	.5	1.
pH	6.8	6.0 - 9.5	
Phenol	.05		1.
Suspended Solids	2		

All results expressed in mg/l with the exception of pH which is expressed in pH units.

PCB *

.5 PPB

10

LYCOTT ENVIRONMENTAL RESEARCH, INC.

BY Kate Schuniger

* See attached

STATE CERTIFIED LABORATORY

MONSANTO INDUSTRIAL CHEMICALS CO.
 Sauget, Illinois 62201
 Phone: (618) 271-5835

December 31, 1974

Mr. Clifford H. Tuttle
 Aerovox Industries, Inc.
 740 Belleville Avenue
 New Bedford Mass. 02741

Dear Mr. Tuttle:

Re: "AD HOC PCB Committee"

Tabulated below are the PCB analyses of various samples taken on 12/4 and 12/5/74.

All PCB concentrations are expressed in micrograms per liter. Same as parts per billion (ppb).

- | | PCB's | |
|--|----------|--|
| I. Composite sample taken 12/4 & 12/5/74
(Sample at main plant effluent taken from moat discharge at north side of building. Rough flow measured at 430 GPM,* but could be less. Composite obtained over 18 hr. sampling period.) | 19.7 ppb | 760 |
| II. Grab sample taken 12/5/74
(Main plant effluent from same spot as I above. Sample in AM when composite sampler was removed.) | 55.3 ppb | 761 |
| III. Grab sample taken 12/5/74
(At pumphouse in parking lot. Possible flow to New Bedford sewer system.) | 5 ppb | 762 |
| | 6 | Per Ed Stewart
1/20/75. Second sample |
| IV. Plant water taken 12/5/74
(Grab sample taken from drinking fountain.) | 2.5 ppb | 763 |
| V. Estuary taken 12/5/74
(Grab sample taken along shore line just south of main plant effluent discharge from north moat.) | 26 ppb | 764 |
| VI. Estuary taken 12/5/74
(Grab sample taken along shore line below parking lot.) | 18 ppb | 765 |

The above information, plus flow data from your plant, should permit you to complete the EIA questionnaires. Norm Butterworth is familiar with how and

* Rate of approx. 620,000 gals. per day.

NEW ENGLAND ANALYTICAL & TESTING LABORATORY

2 SHADY OAK LANE
HATICK, MASS. 01760
(area 617) 873-8169

January 6, 1975

REPORT OF ANALYSIS

For: Cornell Public Electronics
Div. of Federal Pacific Elec. Co.
1005 Federal Branch Blvd.
New Bedford, Mass. 02741

P.O. # 4-53938
Packing List R-46809

Attn: Mr. Curtis A. Lopes

Problem: To analyze samples for polychlorinated bi-phenols, (PCB's)
contamination.

Instrument: Gas Chromatograph with Electron Capture Detector.

Results: Based on 100% standard. All samples resolved two different
Arachlors.

Sample

Arachlor 1016

Arachlor 1254

Continuous North West Aerover

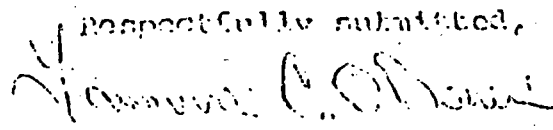
16 ppb.

2.73 ppb.

744

747

Respectfully submitted,


LAWRENCE C. O'BRIEN

IC03B;co

